Fishery Data Series No. 00-39

Characteristics of the Spring Population of Arctic Grayling in the Chena River in 1998 and 1999

by

William P. Ridder

December 2000

Alaska Department of Fish and Game

Division of Sport Fish

Symbols and Abbreviations

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Weights and measures (metric)

centimeter	cm
deciliter	dL
gram	g
hectare	ha
kilogram	kg
kilometer	km
liter	L
meter	m
metric ton	mt
milliliter	ml
millimeter	mm

Weights and measures (English)

cubic feet per second	ft^3/s
foot	ft
gallon	gal
inch	in
mile	mi
ounce	oz
pound	lb
quart	qt
yard	yd

Spell out acre and ton.

Time and temperature

day	d
degrees Celsius	°C
degrees Fahrenheit	°F
hour (spell out for 24-hour clock)	h
minute	min
second	s

Spell out year, month, and week.

Physics and chemistry

all atomic symbols	
alternating current	AC
ampere	A
calorie	cal
direct current	DC
hertz	Hz
horsepower	hp
hydrogen ion activity	pH
parts per million	ppm
parts per thousand	ppt, ‰
volts	V
watts	W

General

All commonly accepted abbreviations.	e.g., Mr., Mrs., a.m., p.m., etc.
All commonly accepted professional titles.	e.g., Dr., Ph.D., R.N., etc.
and	&
at	@
Compass directions:	
east	E
north	N
south	S
west	W
Copyright	©
Corporate suffixes:	
Company	Co.
Corporation	Corp.
Incorporated	Inc.
Limited	Ltd.
et alii (and other people)	et al.
et cetera (and so forth)	etc.
exempli gratia (for example)	e.g.,
id est (that is)	i.e.,
latitude or longitude	lat. or long.
monetary symbols (U.S.)	\$, ¢
months (tables and figures): first three letters	Jan,...,Dec
number (before a number)	# (e.g., #10)
pounds (after a number)	# (e.g., 10#)
registered trademark	®
trademark	™
United States (adjective)	U.S.
United States of America (noun)	USA
U.S. state and District of Columbia abbreviations	use two-letter abbreviations (e.g., AK, DC)

Mathematics, statistics, fisheries

alternate hypothesis	H_A
base of natural logarithm	e
catch per unit effort	CPUE
coefficient of variation	CV
common test statistics	F, t, χ^2, etc.
confidence interval	C.I.
correlation coefficient	R (multiple)
correlation coefficient	r (simple)
covariance	cov
degree (angular or temperature)	°
degrees of freedom	df
divided by	÷ or / (in equations)
equals	=
expected value	E
fork length	FL
greater than	>
greater than or equal to	≥
harvest per unit effort	HPUE
less than	<
less than or equal to	≤
logarithm (natural)	ln
logarithm (base 10)	log
logarithm (specify base)	log_2, etc.
mideye-to-fork	MEF
minute (angular)	'
multiplied by	x
not significant	NS
null hypothesis	H_O
percent	%
probability	P
probability of a type I error (rejection of the null hypothesis when true)	α
probability of a type II error (acceptance of the null hypothesis when false)	β
second (angular)	"
standard deviation	SD
standard error	SE
standard length	SL
total length	TL
variance	Var

FISHERY DATA SERIES NO. 00-39

CHARACTERISTICS OF THE SPRING POPULATION OF ARCTIC GRAYLING IN THE CHENA RIVER IN 1998 AND 1999

by

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December 2000

Development and publication of this manuscript were partially financed by the Federal Aid in Sport Fish Restoration Act (16 U.S.C. 777-777K) under Projects F-10-15, Job No.R-3-2(a), and F-10-14, Job No.R-3-2-(a).

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This document should be cited as:
Ridder, W. P. 2000. Characteristics of the spring population of Arctic grayling in the Chena River in 1998 and 1999. Alaska Department of Fish and Game, Fishery Data Series No. 00-39, Anchorage.

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ABSTRACT

Characteristics of Arctic grayling *Thymallus arcticus* found in the lower 144 km of the Chena River during May and July of 1998 and 1999 were described with estimated abundance, fidelity, and length and age composition. Estimated abundance in May 1998 was 18,861 (SE = 2,491) Arctic grayling ≥ 270 mm FL. Ages of fish sampled in 1998 ranged from age-3 to age-13 and in 1999 from age-2 to age-12. The age class with the greatest number of fish in the sample was age-7 in both years. Of fish sampled ≥ 150 mm FL, quality-sized Arctic grayling (270 – 339 mm FL) constituted 56% and 58% of the samples in the two years. Of fish tagged in May 1998 and recovered in May 1999, eighty-five percent that were marked in the lower 72 km of the study area were recovered within 8 km of the location of release compared to 61% that were marked in the upper 72 km. Within the study area, 42% of the July 1998 adult population (fish ≥ 270-mm FL) were also present in the May 1998 population. Estimated abundance of Arctic grayling ≥ 270 mm FL in the Chena River drainage above the lower 144 km in July 1998 was 34,717 (SE = 10,011).

Key words: Arctic grayling, *Thymallus arcticus*, spawning, electrofishing, population abundance, composition, spawner abundance, spawner distribution, maturity, movements, homing, contribution rate, angler recaptures, Chena River.

INTRODUCTION

The Chena River is a clear-water tributary to the Tanana River originating in the Tanana Uplands 144 km east of Fairbanks. The Chena River drainage flows approximately 252 km from the uppermost reach in the East Fork Chena River to the confluence of the Chena River with the Tanana River at Fairbanks. The Chena River drains a watershed of 5,130 km^2 that includes five major tributaries: North Fork Chena, West Fork Chena, South Fork Chena, East Fork Chena, and the Little Chena rivers (Figure 1). Collectively, these major tributaries and the mainstem are over 470 km in length. Urban development is extensive along the lower 40 km of the river and road accessibility extends along a majority of the lower 183-km.

The Chena River provides habitat for at least 14 fish species: Arctic grayling *Thymallus arcticus*, chinook salmon *Oncorhynchus tshawytscha*, chum salmon O. *keta*, round whitefish *Prosopium cylindraceum*, slimy sculpin *Cottus cognatus*, burbot *Lota lota*, longnose sucker *Catostomus catostomus*, Arctic lamprey *Lampetra japonica*, northern pike *Esox lucius*, sheefish *Stenodus leucichthys*, humpback whitefish *Coregonus pidschian*, broad whitefish *C. nasus*, least cisco *C. sardinella*, and lake chub *Couesius plumbeus*. The latter six of these species are associated with the lower river and the other eight with all the major tributaries of the drainage. Recreational fisheries occur on Arctic grayling, salmon, northern pike, burbot, and whitefish.

Quality of fishing, proximity to Fairbanks, and road accessibility allows the Chena River to support the largest Arctic grayling fishery in North America. The status and character of the fishery, however, has changed since 1985. From 1977 through 1984, the estimates of harvest of Arctic grayling averaged 30,000 fish annually and the estimate of angling effort for all species averaged 34,000 angler days annually (Mills 1979-1985; Table 1; Figure 2). In 1985, the estimate of harvest declined to 6,240 Arctic grayling and the estimate of effort decreased to 19,737 angler days (Mills 1986; Table 1). Concomitant with the decline in the estimate of harvest was a decline in the estimate of abundance. Stock assessment projects during 1986 (Clark and Ridder 1987) and 1987 (Clark and Ridder 1988) indicated an estimated decline in abundance of about 50%. Even though the estimated decline in abundance paralleled changes in

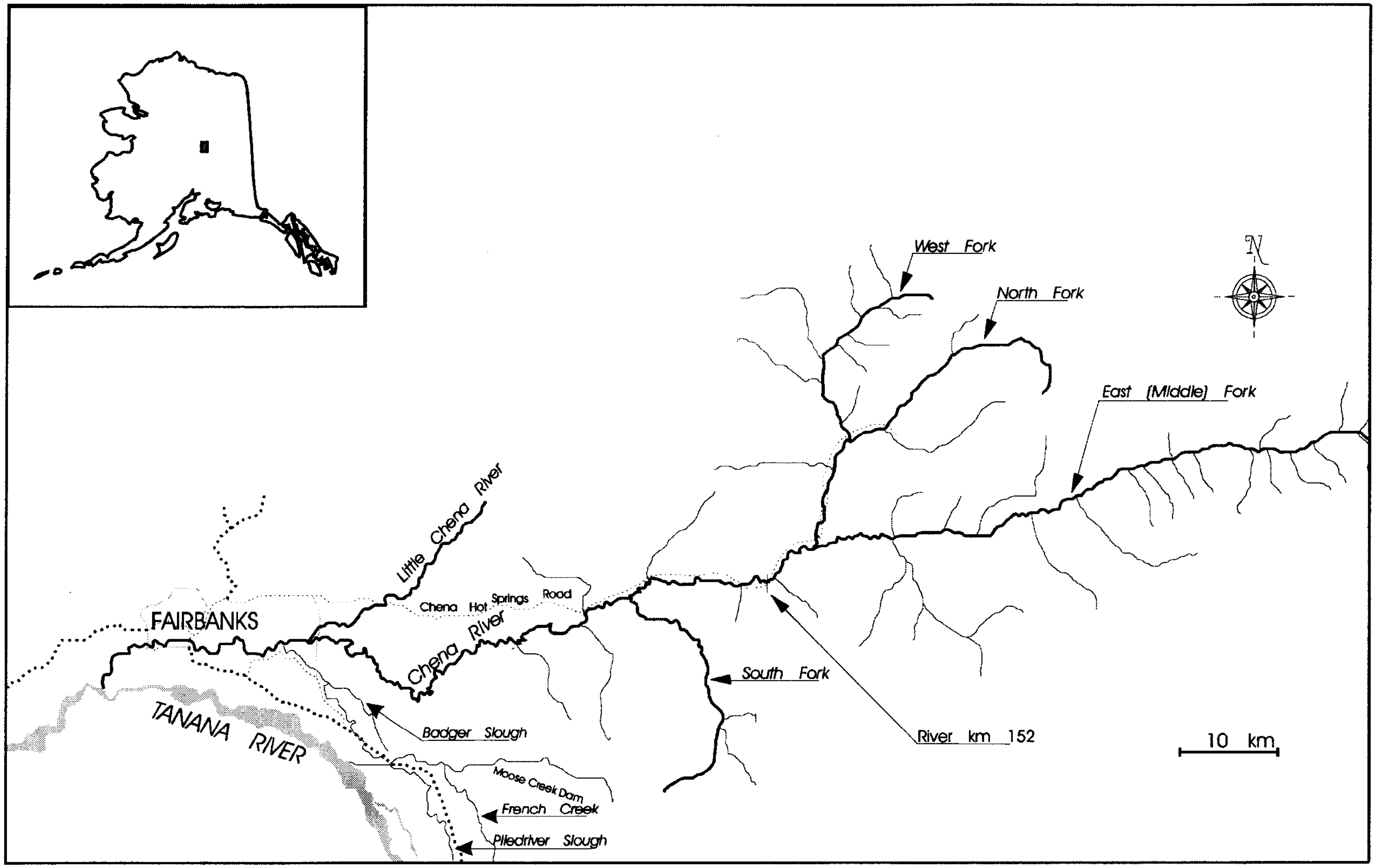

Figure 1.-The Chena River drainage.

Table 1.-Angler days, harvest, and catch of Arctic grayling from the Chena River drainage, 1977-1998.

Year	Below River-Km 114[a]			Above River-Km 114[b]			Entire Chena River Drainage		
	Angler-Days[c]	Harvest	Catch	Angler-Days	Harvest	Catch	Angler-Days[c]	Harvest	Catch
1977	---	---	---	---	---	---	30,003	21,723	---
1978	---	---	---	---	---	---	38,341	33,330	---
1979	9,430	11,290	---	8,016	11,664	---	17,446	22,954	---
1980	13,850	18,520	---	10,734	16,588	---	24,584	35,108	---
1981	11,763	10,814	---	10,740	13,735	---	22,503	24,549	---
1982	18,818	11,117	---	15,166	12,907	---	33,984	24,024	---
1983	17,568	7,894	---	16,725	10,835	---	34,293	18,729	---
1984	20,556	13,850	---	11,741	12,630	---	32,297	26,480	---
1985	11,169	2,923	---	8,568	3,317	---	19,737	6,240	---
1986	18,669	4,167	---	10,688	3,695	---	29,357	7,862	---
1987[d]	12,605	1,230	---	10,667	1,451	---	23,727	2,681	---
1988[d,e]	16,244	2,686	---	9,677	1,896	---	25,921	4,582	---
1989[d,e]	20,317	7,194	---	10,014	5,441	---	30,331	12,635	---
1990[d,e,f]	18,957	3,494	22,062	6,949	945	10,769	25,906	4,439	32,831
1991[d,e,f,g]	12,547	2,997	14,860	8,591	722	14,688	21,138	3,719	29,548

-continued-

[a] The Statewide Harvest Survey refers to the mouth upstream to 40-km Chena Hot Springs Road (approximately river-km 114) as the Lower Chena River (Mills 1988). For 1991 through 1996 the Lower Chena River included Badger Slough. Angling effort is for all species of fish.

[b] The Statewide Harvest Survey refers to the Chena River drainage upstream of 40-km Chena Hot Springs Road as the Upper Chena River (Mills 1988). Angling effort is for Arctic grayling.

[c] Angler-days and harvest included Badger Slough.

[d] Special regulations were in effect during 1987 through 1991. These regulations were catch-and-release fishing from 1 April until the first Saturday in June, a 305 mm (12 inch) minimum length limit, and a restriction of terminal gear to unbaited artificial lures.

Table 1.-Page 2 of 2.

Year	Below River-Km 114[a]			Above River-Km 114[b]			Entire Chena River Drainage		
	Angler-Days[c]	Harvest	Catch	Angler-Days	Harvest	Catch	Angler-Days[c]	Harvest	Catch
1992[h]	7,671	0	11,270	4,983	0	9,039	12,654	0	20,309
1993[h]	15,631	0	26,805	6,018	0	17,173	21,649	0	43,978
1994[h]	18,718	33	32,759	7,912	82	27,193	26,630	115	59,952
1995[h]	23,219	0	15,181	13,319	212	23,428	36,538	212	38,609
1996[h]	30,714	0	23,278	15,228	0	26,805	45,942	0	50,083
1997[h]	22,800	0	28,796	14,838	0	42,572	37,638	0	71,368
1998[h]	21,362	0	39,063	13,601	0	49,924	34,963	0	88,987
Average	17,206,	---	23,786	10,709	---	24,621	31,100	---	48,745

Modified from: Mills (1979-1994) and Howe et al. (1995-1999).

[e] In addition to the special regulations, a catch-and-release area was created from river-km123.2 to 140.8.

[f] The daily bag and possession limits were reduced from five fish to two fish in 1990.

[g] During 1991, the Chena River and its tributaries were closed to possession of Arctic grayling from 1 July through 31 December.

[h] During 1992 through 1998, the Chena River and its tributaries were closed to possession of Arctic grayling from 1 January through 31 December.

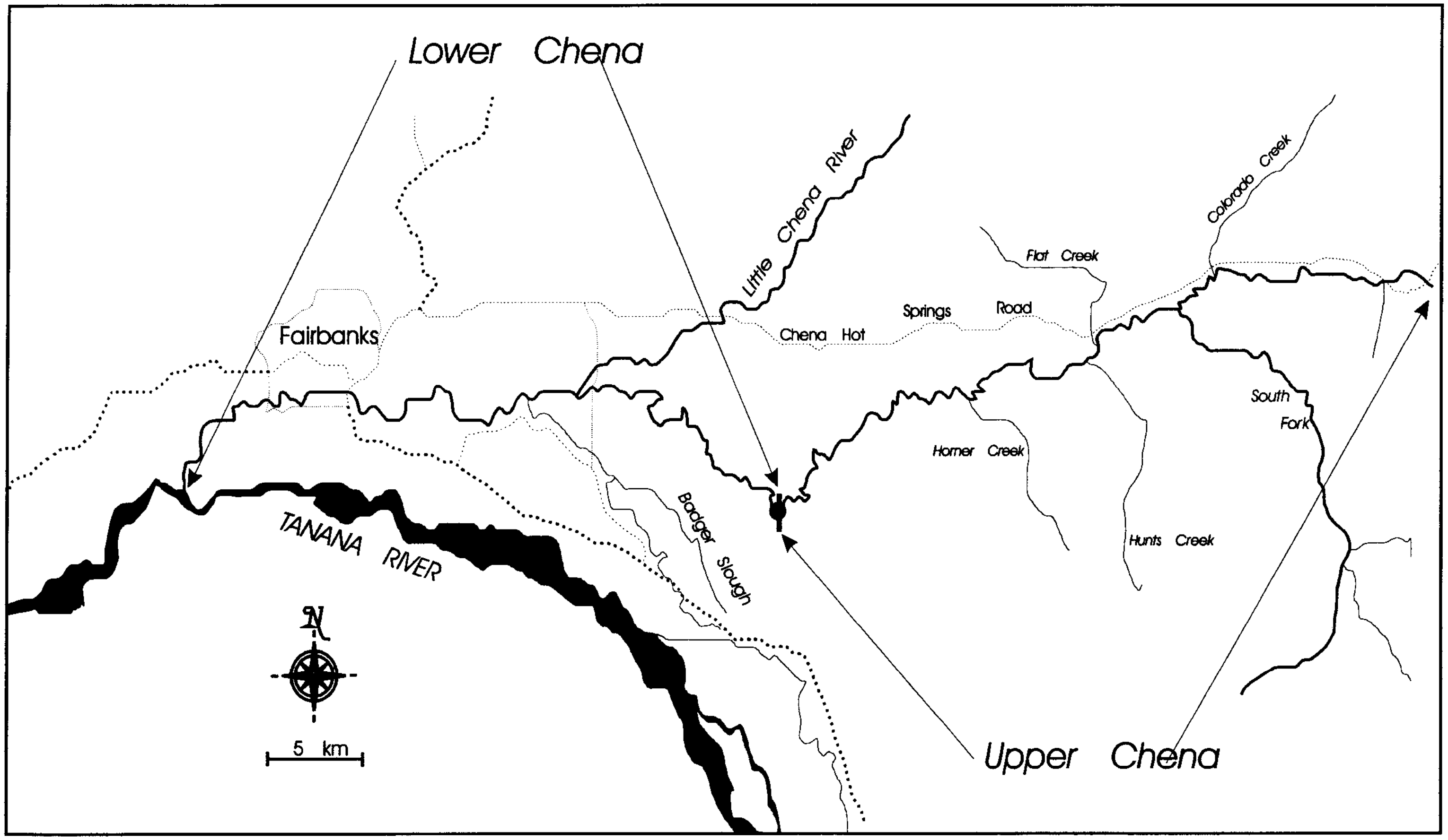

Figure 2.-Study area sections for stock assessment along the lower 144 km of the Chena River drainage in 1999.

sampling design, fishery managers were confident that the decline in abundance was dramatic and processed emergency regulations for the 1987 fishing season to reduce harvest (see Table 1 footnotes). These were the first changes in regulations for Arctic grayling in the Chena River since 1975 at which time the daily bag limit was reduced from 10 to 5 fish.

By 1990, after four years of special regulations, estimates of July abundance in the lower 144 km indicated that the population was not increasing as rapidly as expected. This prompted the Alaska Board of Fisheries (BOF) to further restrict the fishery to a daily-bag limit of two fish drainage wide and to adopt single hook regulations upstream of the Moose Creek Dam. Furthermore, on 1 July 1991, fishery managers issued an emergency order that reduced the daily bag limit to 0 fish throughout the Chena River drainage. This restriction remained an emergency order through 1994, at which time the BOF passed a regulation to keep the daily bag limit at 0 fish. Since the imposition of a zero bag limit, estimates of July abundance of Arctic grayling ≥ 150 mm FL in the lower 144 km of the Chena River increased from 26,800 (SE = 3,300) fish in 1991 to 45,100 (SE = 4,400) fish in 1995 and then decreased to 27,600 (SE = 3,600) in 1998. However, estimates of abundance of fish age-5 and older increased from 7,900 (SE = 600) fish in 1991 to an average of 14,100 fish between 1992 and 1998 [ranged from 10,400 (SE = 1,200) to 19,700 (SE = 1,200)]. Estimates of catch and effort for Arctic grayling in the Chena River have both increased since the first full year of catch-and-release only fishing. Estimates of angling effort increased from 12,654 angler days in 1992 to 45,942 angler days in 1996 and the catch of Arctic grayling increased from 29,548 fish in 1991 to 88,987 in 1998 (Table 1).

Since 1967, assessments of the Chena River Arctic grayling population have been conducted in the lower 144-km of the river in June and July. Until 1987, the assessed areas consisted of three to four 4.8-km sections. In 1987 the assessed areas were expanded to include an additional 72-km of the river and in 1991 these areas were further expanded to include the entire river from river-km 8 to 144. After 1987, the stock assessment program was designed to allow managers to more accurately assess the population's response to the conservative regulations enacted in 1987. The program provided estimates of parameters necessary for describing stock status on an annual basis that were specific to time (July) and place. Riverine Arctic grayling populations stratify in summer by maturity. Juveniles typically inhabit the lower reaches of the river, both juveniles and sub-adults the middle reaches, and adults in the upper reaches (Tack 1980).

The 144-km long assessed study area comprises approximately 70% of the fished portion of the drainage (Clark 1992a) and, at most, 30% of the entire drainage. Since Arctic grayling inhabit the entire drainage (Tack 1980) and riverine stocks of Arctic grayling typically exhibit annual movements between overwintering, spawning, and summer feeding areas (Tack 1980; Ridder 1991 and 1998a; Northcote 1995) it is important to relate the assessed population to the entire population.

Similar to recent findings on Arctic grayling in the lower 52 km of the Goodpaster River (Ridder 1998b), studies on the Chena River (Ridder 1998c) indicated that the age and size composition of the spring spawning population was significantly different from that observed during the summer assessment. The Goodpaster research estimated the abundance of adult fish (≥ 270 mm FL) 80 to 90% greater during May than in late summer. In the Chena River, 30 to 40% of the adult Arctic grayling present during the summer above river-km 144 overwintered and spawned within the lower 144 km of the river (Ridder 1998c). This spatial and temporal distribution of Arctic grayling within the Chena River drainage must be considered in understanding and managing this fishery effectively.

Prior to 1998, little was known about the May distribution and abundance of spawning Arctic grayling in the Chena River. Hallberg (1978) reported 3 of 55 Arctic grayling examined in the East Fork on 22 June 1977 as gravid. In late May 1991 and 1992, Clark (1992b) sampled 898 fish at seven locations between river-km 10 and 80 and reported 365 fish of these fish gravid. In 1993, 139 gravid fish were easily collected in 23 minutes at river-km 50 on 3 May (Ridder *Unpublished*). Tack (1980) hypothesized that Arctic grayling seek out portions of a drainage that warm quickly in the spring for spawning and thus affording maximal growth for progeny. In the clear-water tributaries of the Tanana River drainage such as the Chena River, the lower reaches warm earlier than the upper reaches (Ridder 1998b). Even though Arctic grayling spawn throughout the Chena River (Ridder 1998c), the greatest production may be in the lower reaches similar to the Goodpaster River (Tack 1980). In 1995, 86% of adult fish that summered in the lower 112 km of the Goodpaster River spawned in the lower 52 km of that river (Ridder 1998b).

The design of the present study assumed that Arctic grayling exhibit annual fidelity (homing) to spawning and summer feeding areas. Homing to summer feeding areas was shown for Arctic grayling populations in the Chena and Delta Clearwater rivers (Clark 1993; Ridder 1998a, 1998c). A number of investigators have presented data that support the homing of Arctic grayling to summer feeding areas in other river systems (Tack 1980; Falk et al. 1982; Ridder 1991; Northcote 1993).

Investigators believe the fidelity of Arctic grayling is as strong to spawning areas as the fidelity to summer feeding areas. Numerous tagging studies within the Tanana River drainage have not revealed multiple spawning areas for the same fish (Ridder 1991). In addition to fidelity, recent research in the Goodpaster River also suggests that homing to the natal stream is site specific within that stream. Of Arctic grayling recaptured one year after being tagged during the time of spawning in the lower 52 km of the Goodpaster River, 53% to 60% were recaptured within 1.6 km of the release site and 76% to 82% within 8 km (Ridder *Unpublished*). Of Arctic grayling recaptured two years after being tagged, 41% were recaptured within 1.6 km of the release site and 79% within 8 km. Further study of abundance and composition of the spawning component of Arctic grayling in the Chena River will substantially enhance the understanding of this population.

Since spring-spawning composition is not the same as the summer-feeding composition, it is important to tie the time of assessment to a precise environmental time. The time of ice-out affords a recognizable environmental time. There are, however, difficulties with in-season experiments to estimate abundance immediately after ice-out because, depending on temperatures, post-spawning movements may occur within a typical two-sample mark-recapture experiment (Ridder 1998b). Multiple year experiments at this time of year, however, may be more viable since the event within any one-year can be conducted in half the time needed for the two events of an in-season experiment. The fidelity of Arctic grayling to spawning areas makes multiple year experiments suitable for estimating abundance of populations of spawning Arctic grayling.

Objectives for Stock Assessment

The goal of this study was to accurately describe the spring Arctic grayling population in the lower 144 km of the Chena River by meeting the following objectives:

1. estimate abundance of Arctic grayling (≥ 150 mm FL[1]) in the lower 144 km of the Chena River in May 1998;
2. estimate the relative contribution of Arctic grayling (≥ 150 mm FL[1]) that were marked and released in the lower 144 km of the Chena River in May 1998, and recovered in the lower 144 km of the Chena River in July 1998;
3. estimate age composition of Arctic grayling (≥ 150 mm FL[1]) in the Chena River in May 1999; and,
4. estimate length composition of Arctic grayling (≥ 150 mm FL[1]) in the Chena River in May 1999.

METHODS

In 1998 and 1999, a mark-recapture experiment was conducted to estimate the abundance of Arctic grayling present in the lower 144 km of the Chena River in May 1998 (data files were archived; see Appendix A1). The study area for the mark recapture experiment did not include Badger Slough, Little Chena, South Fork Chena, West Fork Chena, North Fork Chena, or East Fork Chena rivers. For the estimate and to compare to other studies, the lower 144-km of the Chena River was divided into two sections based on differences in capture probability in some previous mark-recapture experiments. The two sections were divided at the Moose Creek Dam. The lower section of the study area was downstream from the dam to the mouth and the upper section of the study area was upstream from the dam to the first bridge at 62.4-km Chena Hot Springs Road.

SAMPLING GEAR AND TECHNIQUES

During 1998 and 1999, all fish were captured using pulsed-DC electrofishing systems that were mounted on 6.1-m long riverboats similar to that described by Lorenz (1984). Input voltage (240 V AC) was provided by a 3,500 or 3,800 W single-phase gas powered generator. A variable-voltage pulsator (Coffelt Manufacturing Model VVP-15[2]) was used to generate output current. Anodes were constructed of twisted steel cable that was 16.0 mm in diameter and 1.5 min length. Four anodes were connected to a t-boom that was 3 m in length. The boom was attached to a platform at the bow of the riverboat. The aluminum hull of the riverboat was used as the cathode. Output voltages during sampling varied from 200 to 300 V DC and amperage from 2.5 to 4.0 A. Duty cycle was 50% and pulse rate was 60 Hz.

Two pulsed-DC electrofishing boats were used in 1999, although only one boat sampled any given reach. In 1998, only one boat was used to sample all reaches of the study area. In 1999 (Ridder 1999), sampling proceeded up the river in approximately 36-km increments. In the first two days one boat sampled the lower-36 km and one boat sampled from river-km 72 to 36, after which, one boat sampled from river-km 108 to 72 and the other from river-km 144 to 108.

The crew within each boat consisted of a driver and two members that captured fish using long-handled dipnets. Sampling was not confined to any one bank but actively moved from bank to bank searching for fish. The boats were operated in this manner since during the spawning period males are spread out near the heads of riffle areas and females at the lower ends of pools when resting (Tack 1980; B. Clark and D. Fleming, Alaska Department of Fish and Game,

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[1] Due to the nature of the estimator used in this experiment, estimates of abundance and composition were only unbiased for fish ≥ 270 mm FL.

[2] Product names used in this publication are included for scientific completeness but do not constitute product endorsement.

Fairbanks, personal communication). Starting at the upstream end of a section, sampling proceeded downstream in 20 to 25 minute "runs" that covered between 1 and 2 km. At the end of most runs a GPS reading or landmark was noted. River mile for each run was determined using a planimeter to measure linear distance from United States Geological Survey (USGS) maps. At the end of each run, all captured fish >149 mm FL were sampled for length, marked with individually numbered tags, and the right (1998) or left (1999) ventral fin was clipped. Sex was determined for each fish and the degree of maturity in females was noted. Either sexual dimorphism or the presence of milt or eggs was used to determine sex and maturity. Dimorphism is evident in differences in height and length of the dorsal fin and length of the pelvic fin (Bishop 1967). Males have larger and longer dorsal and pelvic fins than females. Degree of maturity in females was determined by swollen anal vents and abdomen fullness (gravid), flaccidity of the abdomen (spawned out), and how easily that eggs flowed (ripe) when the fish were handled (Ridder 1989a and 1989b). Clark (1992a) assessed the error associated with using these characteristics as sex and maturity indicators and found it negligible. Adult males were used to describe spawner distribution since they are the first and last to occupy spawning sites (Beauchamp 1990). Age samples were collected only on odd-numbered runs from all captured fish >150 mm FL.

Water temperatures were recorded hourly with temperature loggers placed at river-km 8, 76, and 144. Preliminary water discharges were recorded daily by the USGS at river-km 152.

ESTIMATION OF ABUNDANCE

The mark-recapture experiment was designed to satisfy the assumptions of a Petersen mark-recapture experiment (Seber 1982) modified by Robson and Flick (1965). These assumptions were that:

1. the population was closed (no change in the number or composition of Arctic grayling in the population during the experiment);
2. all Arctic grayling had the same probability of capture in the first sample <u>or</u> in the second sample, <u>or</u> marked and unmarked Arctic grayling mixed uniformly between the first and second samples;
3. marking of Arctic grayling did not affect their probability of capture in the second sample;
4. Arctic grayling did not lose their mark between sampling events; and,
5. all marked Arctic grayling were reported when recovered in the second sample.

Since the marking and recapture events were one year apart, recruitment and mortality occurred during the experiment. Recruitment was culled out of the experiment by using the nonparametric methods of Robson and Flick (1965), which then left mortality between events as a source of violation of assumption 1. Given that recruitment was culled out and that there was no other movement of new fish into the sampled population the Peterson estimator provided an unbiased estimate for fish fully recruited to the gear at the time of the marking event.

The Robson-Flick technique used the length of each recaptured fish as the upper boundaries for length categories (cells). By plotting running averages of the number of fish examined for marks within each cell and performing a series of hypothesis tests (Bernard and Hansen 1992) the cell in which recruitment was no longer significant was determined. The running average of this cell was an estimate of the ratio of unmarked fish to marked fish in the sampled population. .

The validity of assumption 2 of the experimental population was inferred from comparisons of recapture rates and movements of fish within the study area between events with tests of consistency designed to detect unequal catchability by area (Seber 1982). Since there was a year between events, it is believed that there was not a change in behavior that resulted from the marking of a fish and therefore the validity of assumption 3 was presumed valid. A distinct and permanent marking and rigorous examination for marks of all captured fish ensured the validity of assumptions 4 and 5.

Differences in capture probability by size between events may be due to gear selectivity or by changes in the length composition from one event to the other, which may be caused by behavior or recruitment. The Robson-Flick model, however, only provides unbiased estimates of abundance when the sample of the first event is not size selective (i.e., all fish used in the experiment must be fully recruited to the gear) and all new fish can be culled from the experiment (Bernard and Hansen 1992). Size selectivity in the sample during the second event is of no consequence to the bias of the experiment.

Electrofishing may be selective for the largest fish in a population (Reynolds 1983), so that larger fish may be marked in a greater proportion to density than smaller fish. In typical mark-recapture experiments two Kolmogorov-Smirnov (KS) statistical tests are used to help determine if capture probability differs by size of fish during the marking event. The first KS test compares the length frequency distribution of recaptured Arctic grayling with those released with marks during the marking event. The second KS test compares the length frequency distribution of those fish released with marks in the first event with those that were examined for marks in the second event. Length frequencies must not be significantly different in both cases to make the inference that there was not size selectivity during the marking event. Unfortunately, these tests are not reliable when there is growth or recruitment between events such as the case of this experiment. To alleviate this problem, the Robson-Flick model requires that only fully recruited fish be used in the experiment. Arctic grayling ≥ 270 mm FL were fully recruited to the gear.

The Robson-Flick estimator of abundance was calculated as:

$$\hat{N} = (M+1)(\bar{u}_{r+1}+1)-1 \tag{1}$$

Variance of this estimator was calculated as (Robson and Flick 1965):

$$V[\hat{N}] \approx \frac{(M+1)^2}{(R'+1-r)(R'-r)} \sum_{i=1}^{R'+1-r} (u_{r+1} - \bar{u}_{r+1})^2 \tag{2}$$

where: $\hat{N}$ = the abundance of Arctic grayling in the Chena River study section;

M = the number of Arctic grayling released with marks;

u = the number of unmarked Arctic grayling in a cell;

$\bar{u}$ = the running average of u;

r = the last cell influenced by recruitment; and

R' = number of Arctic grayling recaptured in the second event with unique lengths.

ESTIMATION OF AGE AND LENGTH COMPOSITION

For aging, scales were taken from an area on the fish approximately six scale rows above the lateral line and just posterior to the insertion of the dorsal fin (Ridder *Unpublished*; Brown 1943). Scales were cleaned and mounted on gum cards. The scales were then used to make impressions on triacetate (30 s of 137,895 kPa at 97°C). Ages were determined by counting annuli from the impressions of scales magnified 40X using a microfiche reader. An annulus was noted when: 1) complete circuli cut over incomplete circuli; 2) there were clear areas or irregularities in circuli along the anterior and posterior fields; or, 3) when a region of closely spaced circuli followed a region of widely spaced circuli (Kruse 1959).

Collection of Arctic grayling for age and length sampling was conducted in conjunction with mark-recapture sampling. Because estimates of abundance were germane to the first event, scales and lengths were taken during the marking event. For example, the abundance estimate for 1998 was calculated from fish sampled in both years, but age composition was estimated for 1998 using only the samples taken in 1998. Likewise the age and length composition for 1999 was estimated using only the samples taken in 1999.

Unadjusted age and size data was used to estimate age and size compositions in 1998 and 1999. These compositions may underestimate the compositions of small fish due to the known selectivity of electrofishing gear to large fish. In traditional two sample mark-recapture experiments, a second KS tests are to determine if age and size data need to be corrected for changes in capture probability. However, the testing is not conclusive in multiple year experiments since variable recruitment between the two years may be the causative factor in a significant finding and not gear selectivity. The proportion (p_k) of Arctic grayling in the sample that were age k was estimated by:

$$\hat{p}_k = \frac{y_k}{n} \tag{3}$$

where y_k = the number of Arctic grayling in the sample that were age or length k; and, n = the total number of Arctic grayling sample.
The variance of this proportion was estimated as:

$$\hat{V}[\hat{p}_k] = \frac{\hat{p}_k(1-\hat{p}_k)}{n-1} \tag{4}$$

PROPORTION OF JULY FISH ALSO PRESENT IN MAY

To estimate the proportion of July fish also present in the May population, the following was needed:

$n_j \equiv$ number of fish in the July sample that were examined for tags;

$c_m \equiv$ number of fish in the July sample that carried May tags;

$n_m \equiv$ number of fish tagged in May;

$N_m \equiv$ population size in May;

$p_t \equiv$ Probability that a fish was tagged in May; and,

$p_c \equiv$ Probability that a fish in the July population was also present in the May population.

The rate fish were tagged in May was estimated as:

$$\hat{p}_t = \frac{n_m}{\hat{N}_m}. \tag{5}$$

Given the assumption that the movement of May fish was independent of whether or not it was tagged in May, the expected number of fish tagged in May that would also be found in the July sample was:

$$E[c_m] = n_j p_c p_t. \tag{6}$$

This can be rearranged to estimate p_c,

$$\hat{p}_c = \frac{c_m}{\hat{p}_t n_j} \tag{7}$$

$$= \frac{c_m}{n_j}\left(\frac{\hat{N}_m}{n_m}\right). \tag{8}$$

Given that the parameters n_j and c_m were independent of $\hat{N}_m$ and n_m the variance estimate for c_m was a binomial count, $n_j(\hat{p}_t\hat{p}_c)(1-\hat{p}_t\hat{p}_c)$ and the estimate of variance for $\hat{p}_c$ was:

$$\mathrm{var}(\hat{p}_c) = \left(\frac{1}{n_j n_m}\right)^2 \left[c_m^2 \,\mathrm{var}(\hat{N}_m) + \hat{N}_m^2 \,\mathrm{var}(c_m) - \mathrm{var}(\hat{N}_m)\mathrm{var}(c_m)\right]. \tag{9}$$

ABUNDANCE OF ARCTIC GRAYLING UPSTREAM OF STUDY AREA

From a radiotelemetry study of adult Arctic grayling ≥ 340 mm FL it was learned that a portion of fish that summered in the Chena River drainage above the study area in 1997 spawned in the study area in May 1998 (Ridder 1998c). This proportion can probably be generalized to represent movements of all adult-sized fish (≥ 270 mm FL) that summer above the study area. An estimate of abundance of Arctic grayling ≥ 270 mm FL found in the drainage above the study area can be derived using this proportion, estimates of abundance for the study area for May and July, and the proportion of July fish also present in the May population.

The 1998 radiotelemetry study estimated that 37% of adult fish outside the study area during the summer feeding area spawned in the study area in May. The number of radio-tagged adult fish that left the study area after May spawning can be interpreted as representing 37% of adults that summered upstream of the study area moved into the study area to spawn. The abundance of adult-sized fish within the drainage upstream of the study area can then be estimated for the summer of 1998. Adult-sized fish were defined as those fish with lengths greater than or equal to 270 mm FL, which was based on the maturity schedules estimated by Clark (1992b) where 50% of fish of this size were mature.

To estimate the number of fish ≥ 270 mm FL in the drainage above the study area (N_u), p was defined as the proportion of fish that summered above the study area that also spawned in the study area in May. N_j was defined as the abundance of fish ≥ 270 mm FL within the study area in July.

$$pN_u = N_m - (p_c N_j). \tag{10}$$

This was rearranged to estimate N_u,

$$\hat{N}_u = \frac{\hat{N}_m - (\hat{p}_c \hat{N}_j)}{\hat{p}} \tag{11}$$

$$= \frac{\hat{N}_m}{\hat{p}}\left[1 - \frac{c_m \hat{N}_j}{n_j n_m}\right]. \tag{12}$$

This requires the assumption that fish present in the study area in May either remained in the study area or upstream of the study area in July.

For calculating the variance of $\hat{N}_u$ by the delta method, $\theta \equiv (\hat{N}_m, \hat{p}, c_m, \hat{N}_j)'$ was defined. The July estimate $\hat{N}_j$ depended on the number of recaptures from the first event of the July 2-event mark-recapture survey, which was independent of the number of May tags present in the July population. All elements of θ were assumed to be mutually independent (i.e., covariance equals 0). The vector of first partial derivatives was estimated as:

$$\frac{\partial \hat{N}_u}{\partial \theta} = \begin{bmatrix} \left(\dfrac{\hat{N}_u}{\hat{N}_m}\right) \\ \left(\dfrac{-\hat{N}_u}{\hat{p}}\right) \\ \left(\dfrac{-\hat{N}_m \hat{N}_j}{\hat{p} n_j n_m}\right) \\ \left(\dfrac{-\hat{N}_m c_m}{\hat{p} n_j n_m}\right) \end{bmatrix}. \tag{13}$$

The estimate of variance for $\hat{N}_u$ was:

$$\mathrm{var}(\hat{N}_u) = \sum_{i=1}^{4} \left\{ \left(\frac{\partial \hat{N}_u}{\partial \theta_i}\right)^2 \mathrm{var}(\theta_i) \right\}. \tag{14}$$

RESULTS

In 1998, from 29 April to 9 May 2,632 Arctic grayling (≥ 150 mm FL) were captured between the mouth of the Chena River and river-km 138. Of the 2,631 fish unique to the sample, 2,618 fish were released alive with marks (13 fish died from handling). Of unique fish, 70 fish (2.7%) were originally tagged from other studies.. Mature fish (n = 1,908) composed 73% of the catch and of these fish, the male to female ratio was 2:1 (Appendix B1). Of mature females, 76% (SE = 2%) were classified as green (gravid but not ready to spawn) and 6% (SE = 2%) were classified as spent (Appendix B1). One fish, an adult male, was caught twice. The second time, this fish was caught 48 h after the first capture and 6 km upstream from the original location.

In 1999, from 10 to 13 May 2,927 Arctic grayling (≥ 150 mm FL) were captured between the mouth of the Chena River and river-km 144. Of the 2,924 fish unique to the sample, 2,546 fish were released alive with marks (33 fish died from handling). Of unique fish, 85 fish (3.3%) were recaptures from May 1998 (three of these fish lost their tags between events), 46 fish (1.8%) were originally tagged from other studies. Removals of fish for an egg-take and unavailability of tags on some days prevented marking all releases. Mature fish (n = 1,735) composed 59% of the catch and of these fish the male to female ratio was 1:1 (Appendix B1). Of mature females, 82% (SE = 2%) were classified as green (gravid but not ready to spawn) and less than 2% were classed as spent (Appendix B1). Three fish were caught twice within 24 h: one male moved 11 km upstream after release at river km 67 on 11 May and two females each moved 5 km upstream after release at river km 37 on 10 May.

In both years, sampling began within 3 days of ice out in the lower 150 km of the river. In 1999, water clarity was very poor due to turbidity and high discharge throughout the sampling, however, in 1998 water was low and clear (Figure 3). Water temperatures during sampling were above the threshold for spawning (4 C°; Tack 1980) and similar at river-km 8 and 76 in both years, but cooler and lower than the threshold of 4 C° at river-km 144 in 1999 (Figure 4).

For Arctic grayling, probability of marking and recapture varied among marking locations (Tables 2 - 4; Figure 5). Of the 82 of 85 recaptured fish ≥ 150 mm FL with known capture histories, 30 fish (37%) were recaptured outside the 16 km to 24 km long reaches in which they were released a year earlier (Tables 3 and 5). Sixty seven percent of all movement between reaches was downstream. Of fish that moved between reaches, more fish from the upper section moved downstream (79%) than those from the lower section (45%; Table 4).

ABUNDANCE

For fish ≥ 270 mm FL, 2,116 fish were marked, 2,149 fish were examined for marks of which 71 were recaptures from the first event. The number of recaptures with unique lengths was 55 and the length at which growth recruitment was no longer a factor was 370 mm FL. The abundance of fish ≥ 270 mm FL in the study section was estimated at 18,861 (SE =2,491) fish (Table 6). Apportioning the estimated abundance between the upper and lower study sections according to recaptures by area of marking resulted in an estimate of abundance of 7,704 (SE = 1,673) fish in the lower section and 11,157 (SE = 1,846) in the upper section.

A minimum abundance for fish ≥150-mm FL was also estimated. This is a minimum estimate because all fish ≥150-mm FL are not fully recruited to the gear. The abundance of fish ≥ 150 mm FL in the study section was estimated at 23,335 (SE = 3,082) fish (Table 6).

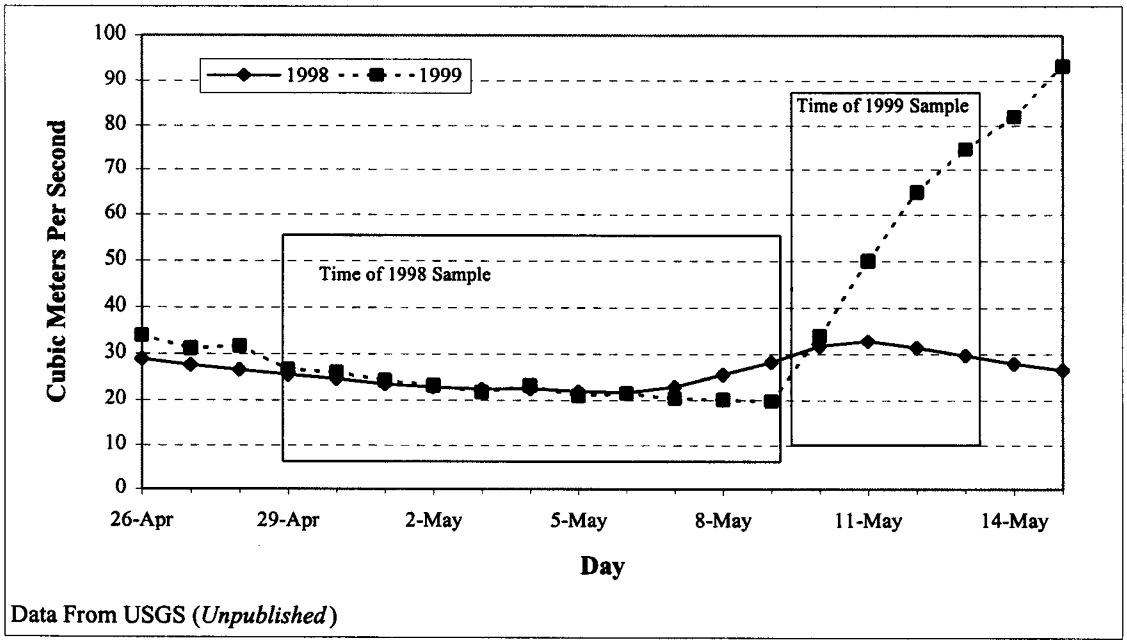


Figure 3.-Daily discharge (m^3/s) for the Chena River at river-km 22 for 26 April - 15 May 1998 and 1999. (Boxes indicate sampling periods.)

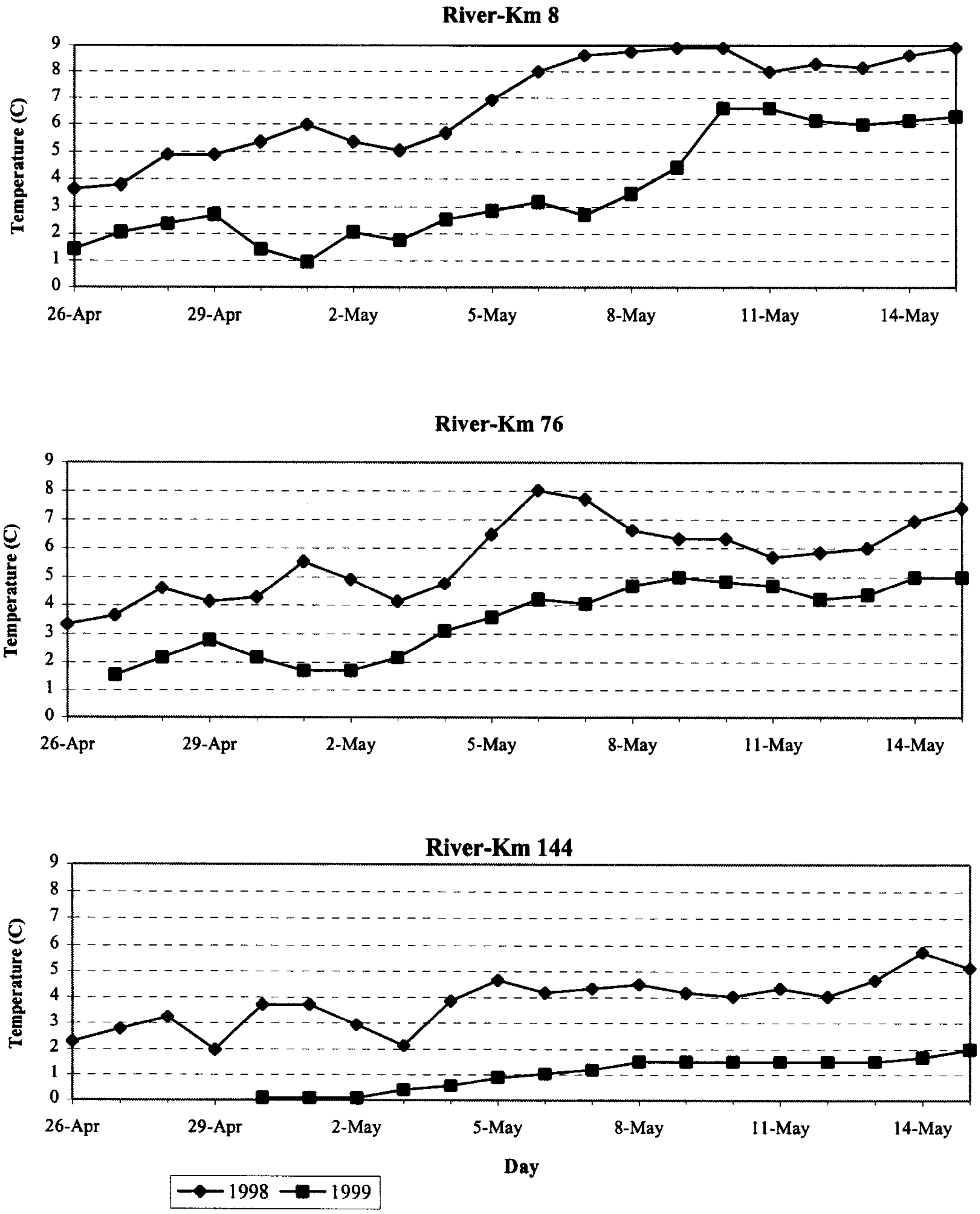


Figure 4.-Maximum daily water temperatures (C°) in the Chena River at river-km 8, 72, and 144, 29 April – 15 May 1998 and 1999.

Table 2.-Unique fish sampled by date, reach, river km, sex for Arctic grayling ≥ 150 mm FL and catch of males per km in the Chena River, spring 1998 and 1999.

Date	Reach	River Km	Female	Male	Unknown	Catch	Males/Km
				1998			
1 May	01	0-24	43	144	46	233	6
29 April	02	24-40	64	207	85	356	13
5 May	03	40-56	112	326	90	528	20
4 May	04	56-72	56	132	68	256	8
Subtotals	01-04	0-72	275	809	289	1,373	11
7 May	05	72-90	77	134	90	301	8
6 May	06	90-107	19	67	44	130	4
8 May	07	107-125	71	81	183	335	5
9 May	08	125-138	184	191	117	492	15
Subtotals	05-08	72-138	351	473	434	1,258	7
Totals	01-08	0-138	626	1,282	723	2,631	9
				1999			
10 May	01	0-24	78	101	74	253	4
10 May	02	24-40	183	216	199	598	14
11 May	03	40-56	191	190	151	532	12
11 May	04	56-72	134	104	107	345	7
Subtotals	01-04	0-72	586	611	531	1,728	8
12 May	05	72-90	88	100	259	447	6
12 May	06	90-107	43	43	127	213	2
13 May	07	107-125	53	75	193	321	4
13 May	08	125-144	60	76	79	215	4
Subtotals	05-08	72-144	244	294	658	1,196	4
Totals	01-08	0-144	830	905	1,189	2,924	6

Table 3.-Rate of marking (R/C), rate of recapture (R/M), location of recapture, and number of marked fish by marking location for 85 recaptured Arctic grayling ≥ 150 mm FL in the lower 144 km of the Chena River, 10 – 13 May 1999.

		Recapture Location								
Marking Location	Marks	01	02	03	04	05	06	07	08	R/M[a]
01	233	1								<0.01
02	354		5	1						0.02
03	524		2	11	4					0.03
04	255			3	5	1				0.04
05	299			1	2	10	2			0.05
06	129	1				3	5			0.07
07	333					1	5	14	2	0.07
08	491							2	1	0.01
Unknown	---				(2)[c]			(1)		
Total	2,618	2	7	16	11	15	12	16	3	0.03
Examined without marks=		252	591	515	334	432	201	305	212	
	R/C[b]=	0.01	0.01	0.03	0.03	0.03	0.06	0.05	0.01	

[a] R/M = recapture rate, number of recaptures divided by number of marked fish released in the first event.

[b] R/C = probability of marking, number of recaptures divided by number of fish examined in second event.

[c] Numbers in parentheses not included in totals or R/C.

Table 4.-Rate of marking (R/C), rate of recapture (R/M), location of recapture, and number of marked fish by marking location for 71 recaptured Arctic grayling ≥ 270 mm FL in the lower 144 km of the Chena River, 10 – 13 May 1999.

		Recapture Location								
Mark Location	Marks	01	02	03	04	05	06	07	08	R/M[a]
01	171	1								0.01
02	242		4	1						0.02
03	438		2	9	3					0.03
04	205			3	3	1				0.03
05	241			1	2	9	2			0.06
06	110	1				3	3			0.06
07	243					1	4	6	1	0.05
08	466						1	6	1	0.02
Unknown					(2)[c]			(1)		
Total	2,116	2	6	14	8	14	10	12	2	0.03
Examined without marks=		151	362	390	255	300	160	260	201	
	R/C[b]=	0.01	0.02	0.03	0.03	0.04	0.06	0.04	0.01	

[a] R/M = recapture rate, number of recaptures divided by number of marked fish released in the first event.

[b] R/C = capture probability, number of recaptures divided by number of fish examined in second event.

[c] Numbers in parentheses not included in totals or R/C.

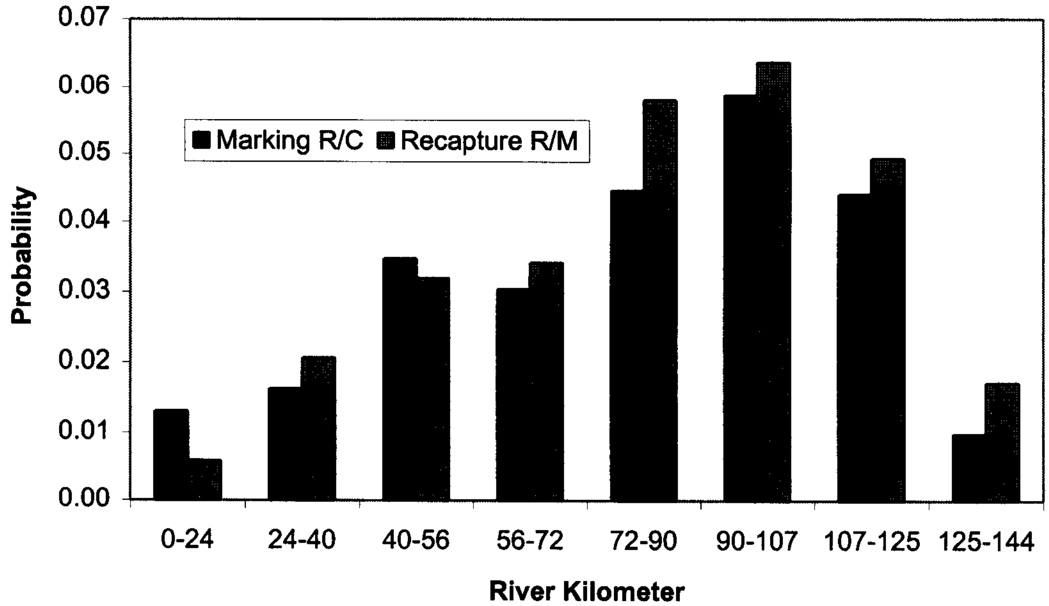


Figure 5.-Probabilities of marking (R/C) and recapture (R/M) an Arctic grayling (≥ 150 mm FL) in eight sections of the Chena River in May 1999.

Table 5.-Number and proportion of Arctic grayling ≥ 150 mm FL (82 of 85) recaptured in same reach or different reach of marking and number and proportion recaptured upstream or downstream from reach of marking, May 1998 to May 1999.

		Number Recaptured							
		Same Reach		Different Reach		Upstream		Downstream	
Section	Total	n	p	n	p	n	p	n	p
Lower	33	22	0.67	11	0.33	6	0.55	5	0.45
Upper	49	30	0.61	19	0.39	4	0.21	15	0.79
Total	82	52	0.63	30	0.37	10	0.33	20	0.67

Table 6.-Robson-Flick statistics and estimates of abundance for Arctic grayling ≥ 150 mm FL and ≥ 270 mm FL in the Chena River, May 1998 - 1999.

						Robson-Flick Statistics[a]							
Section	M(i)	C(i+1)[b]	R(i+1)[b]	R/M[c]	R/C[c]	R'	Length	r	u(r+1)	Sum	N	SE[N]	cv
≥ 150 mm FL:													
	2,618	2,924	85	0.03	0.03	64	370	49	7.9	332.4	23,335	3,082	13%
≥ 270 mm FL:													
	2,116	2,149	71	0.03	0.03	55	370	40	7.9	332.4	18,861	2,491	13%

a R' = the number of recaptures of marked fish (cells) with unique lengths in the second event; Length = the estimated length at which recruitment is negligible (corresponding to cell r+1); r = the last cell (length group) significantly influenced by recruitment; u(r+1) = the running average of unmarked fish in cell r+1; and, Sum = the sum of counts of unmarked fish in cell *i* minus the running average of unmarked fish in cell *i*+1.

b C and R are from year *i*+1. M is from year *i*.

c R/M is the rate of the number of recaptures of marked fish to the total number of marked fish released in the first (mark) event. R/C is the rate of the number of recaptures of marked fish to the total catch of fish in the second (recapture) event.

AGE AND SIZE COMPOSITION

In 1998, 1,062 ages were determined from a sample of 1,221 fish from the study area. Ages ranged from age-3 to age-13 in the lower section and age-4 to age-12 in the upper section (Table 7). Average and median age was the same for each section and the study area, 6.9 years (SD = 1.6 years) and age-7, respectively. Age-6 and older represented 78% of the total sample (Table 7). Of fish ≥ 270 mm FL, ages ranged from age-5 to age-13 (Table 8).

In 1999, 924 ages were determined from a sample of 1,072 fish from the study area. Ages ranged from age-2 to age-12 in the lower section and age-3 to age-11 in the upper section (Table 9). Average age was 7.0 years (SD = 1.9) with a median age of 7 years in the lower section. In the upper section, average age was 6.8 years (SD = 1.4 years) with a median age of 6 years. For the study area, average and median age was 6.9 years (SD = 1.5 years) and 7 years, respectively. Age-6 and older represented 83% of the total sample (Table 9).

Relative Stock Density estimates were significantly different between years for both section and combined samples (chi-square tests, $P < 0.01$) as well as within years between sections (chi-square tests, $P < 0.01$). However, quality size and larger fish (≥ 270 mm FL) predominated in both sectional and combined samples in 1998 (77% - 85%, Table 10) and in 1999 (70% - 80%, Table 11).

Length composition of samples from the lower 144 km of the Chena River were significantly different between 1998 and 1999 ($P=0.00$; Figure 6). In 1999, fish with lengths from 240 mm to 279-mm FL were represented in a greater proportion of the catch than in 1998 and 300-mm to 360-mm FL in a lesser proportion. The increase in proportion of smaller fish was observed in both sections of the study area (Figure 7). Length at age for samples taken in May of 1998 and 1999 are given in Appendix B1 and Appendix B2.

PROPORTION OF JULY FISH ALSO PRESENT IN MAY

In July 1998, 1,697 fish ≥ 270 mm FL were examined for marks of which 80 fish were fish that had been marked in May 1998. These recaptured fish represented 5% of the July sample. The proportion of adult fish present in July that were in the study area in May was estimated as 0.42 (SE = 0.07; Table 12). The proportion of adult fish present in the lower section of the study area in July that was in the lower section in May was 0.24 (SE = 0.06), the proportion present in the upper section in July that was in the lower section in May was 0.15 (SE = 0.04), and the proportion present in the study section in July that was in the lower section in May was 0.18 (SE = 0.05). The proportion of adult fish present in the upper section of the study area in July that was in the upper section in May was 0.34 (SE = 0.06), the proportion present in the lower section in July that was in the upper section in May was 0.00, and the proportion present in the study section in July that was in the upper section in May was 0.24 (SE = 0.05).

Abundance of Arctic Grayling Upstream of Study Area

In 1998, 37% (SE = 9%) of radio-tagged Arctic grayling that were summer residents of the Chena River drainage upstream of the study area moved downstream and spawned within the study area in May. The abundance of adult-sized grayling (≥ 270 mm FL) in the study area in July was 14,323 fish (SE = 1,874 fish; Ridder 1999). The estimated abundance of adult-sized grayling upstream of the study area in July 1998 was 34,717 fish (SE = 10,011). This estimate does not include the abundance of fish in the Little Chena River drainage or Badger Slough.

Table 7.-Numbers sampled and estimated proportions by age for Arctic grayling (≥ 150 mm FL) captured by pulsed-DC electrofishing from two sections of the lower 138 km of the Chena River, 29 April through 9 May 1998.

	Lower Section[a]			Upper Section[b]			Combined		
Age	n[c]	p	SE[p]	n	p	SE[p]	n	p	SE[p]
3	11	0.02	0.01	0	---	---	11	0.01	<0.01
4	29	0.06	0.01	8	0.01	0.01	37	0.03	0.01
5	75	0.15	0.02	107	0.20	0.02	182	0.18	0.01
6	82	0.16	0.02	104	0.19	0.02	186	0.18	0.01
7	124	0.24	0.02	144	0.26	0.02	268	0.25	0.01
8	118	0.23	0.02	102	0.19	0.02	220	0.20	0.01
9	44	0.09	0.01	57	0.10	0.01	101	0.10	0.01
10	23	0.04	0.01	21	0.04	0.01	44	0.04	0.01
11	6	0.01	<0.01	3	0.01	<0.01	9	0.01	<0.01
12	1	<0.01	<0.01	2	<0.01	<0.01	3	<0.01	<0.01
13	1	<0.01	<0.01	0	---	---	1	<0.01	<0.01
Total	514	1.00	---	548	1.00	---	1,062	1.00	---

[a] Lower section = river km 0 – 72 (mouth to Chena Dam).

[b] Upper section = river km 72 – 138 (Chena Dam to 6 km below the first bridge on Chena Hot Springs Road).

[c] n= number of Arctic grayling sampled at age.

Table 8.-Estimates of abundance (N), SE of abundance, and proportion (p) by age for Arctic grayling ≥ 270 mm FL captured by pulsed-DC electrofishing from the lower 138 km of the Chena River, 29 April - 9 May 1998.

Age Class	n	p	SE [p]	N[a]	SE [N]
5	55	0.07	0.01	1,254	504
6	148	0.18	0.01	3,375	509
7	247	0.30	0.02	5,633	709
8	219	0.26	0.02	4,995	586
9	101	0.12	0.01	2,303	297
10	44	0.05	0.01	1,003	148
11	9	0.01	0.00	205	49
12	3	0.00	0.00	68	29
13	1	0.00	0.00	23	12
Total	827	1.00	---	18,861	2,662

Table 9.-Numbers sampled and estimated proportions by age for Arctic grayling ($\geq$ 150 mm FL) captured by pulsed-DC electrofishing from two sections of the lower 138 km of the Chena River, 10 through 13 May 1999.

	Lower Section[a]			Upper Section[b]			Combined		
Age	n[c]	p	SE[p]	n	p	SE[p]	n	p	SE[p]
2	2	<0.01	<0.01	0	---	---	3	<0.01	<0.01
3	11	0.02	0.01	2	<0.01	<0.01	13	0.01	<0.01
4	15	0.03	0.01	8	0.02	0.01	23	0.02	0.01
5	62	0.13	0.02	56	0.13	0.02	118	0.13	0.01
6	92	0.19	0.02	154	0.35	0.02	246	0.27	0.01
7	125	0.26	0.02	84	0.19	0.02	209	0.23	0.01
8	96	0.20	0.02	74	0.17	0.02	170	0.18	0.01
9	55	0.11	0.01	37	0.08	0.01	92	0.10	0.01
10	21	0.04	0.01	17	0.04	0.01	38	0.04	0.01
11	6	0.01	0.01	4	0.01	<0.01	10	0.01	<0.01
12	2	<0.01	<0.01	0	---	---	2	<0.01	<0.01
Total	487	1.00	---	436	1.00	---	924	1.00	---

[a] Lower section = river km 0 – 72 (mouth to Chena Dam).

[b] Upper section = river km 72 – 138 (Chena Dam to 6 km below the first bridge on Chena Hot Springs Road).

[c] n = number of Arctic grayling sampled at age.

Table 10.-Proportion of Arctic grayling ($\geq$ 150 mm FL) sampled and abundance of Arctic grayling ($\geq$ 270 mm FL) by Relative Stock Density (RSD) categories and study section, Chena River 29 April - 9 May 1998.

	Relative Stock Density[a]				
	Stock	Quality	Preferred	Memorable	Trophy
Lower Section of the Study Area					
Number Sampled	191	730	333	0	0
RSD	0.15	0.58	0.27	---	---
SE (RSD)	0.01	0.01	0.01	---	---
N	---	5,291	2,413	0	0
SE (N)	---	1,149	524	---	---
Upper Section of the Study Area					
Number Sampled	305	757	304	0	0
RSD	0.22	0.55	0.22	---	---
SE (RSD)	0.01	0.01	0.01	---	---
N	---	7,662	3,495	0	0
SE (N)	---	1,268	578	---	---
Study Area					
Number Sampled	496	1,487	637	0	0
Adjusted RSD[b]	0.20	0.56	0.24	---	---
SE (RSD)	0.01	0.01	0.01	---	---
N	---	13,204	5,657	0	0
SE (N)	---	1,775	815	---	---

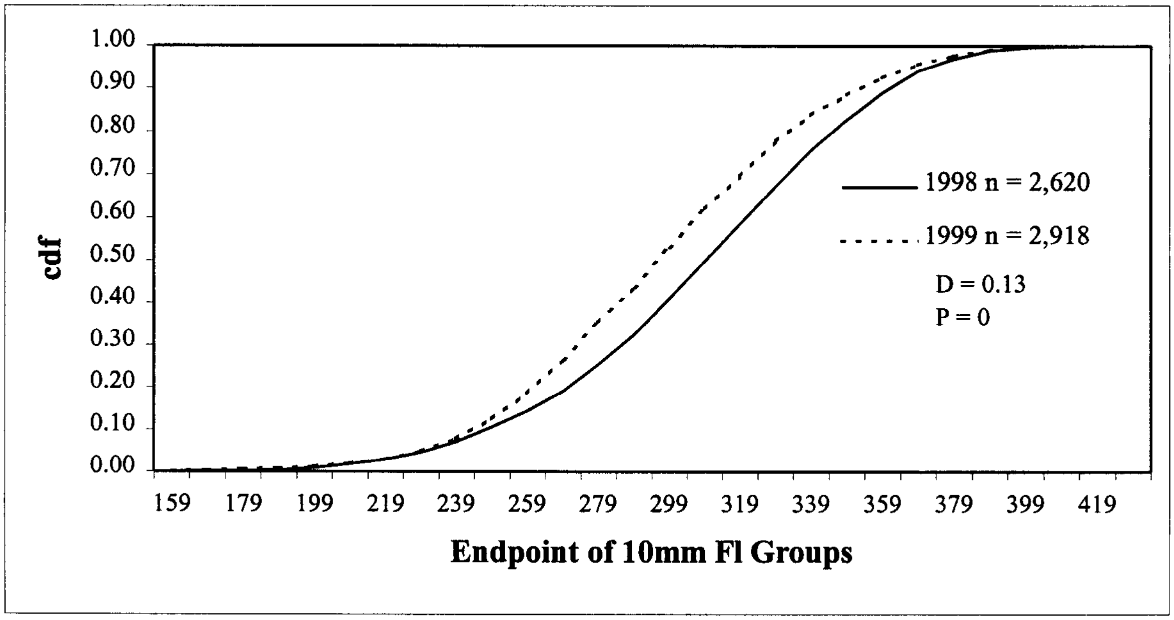
[a] Minimum lengths for RSD categories are (Gabelhouse 1984): Stock – 150 mm FL; Quality – 270 mm FL; Preferred – 340 mm FL; Memorable – 450 mm FL; and, Trophy – 560 mm FL.

[b] Adjusted RSD is the RSD corrected for differential vulnerability by area to the capture method. Standard error of RSD is for the adjusted estimate.

Table 11.- Proportion of Arctic grayling (≥ 150 mm FL) sampled and abundance of Arctic grayling (≥ 270 mm FL) by Relative Stock Density (RSD) categories and study section, Chena River 10 - 13 May 1999.

	Relative Stock Density[a]				
	Stock	Quality	Preferred	Memorable	Trophy
Lower Section of the Study Area					
Number Sampled	537	935	252	0	0
RSD	0.31	0.54	0.15	---	---
SE (RSD)	0.01	0.01	0.01	---	---
Upper Section of the Study Area					
Number Sampled ≥150	235	743	216	0	0
RSD	0.20	0.62	0.18	---	---
SE (RSD)	0.01	0.01	0.01	---	---
Study Area					
Number Sampled	772	1,678	468	0	0
RSD	0.26	0.58	0.16	---	---
SE (RSD)	0.01	0.01	0.01	---	---

[a] Minimum lengths for RSD categories are (Gabelhouse 1984): Stock – 150 mm FL; Quality – 270 mm FL; Preferred – 340 mm FL; Memorable – 450 mm FL; and, Trophy – 560 mm FL.



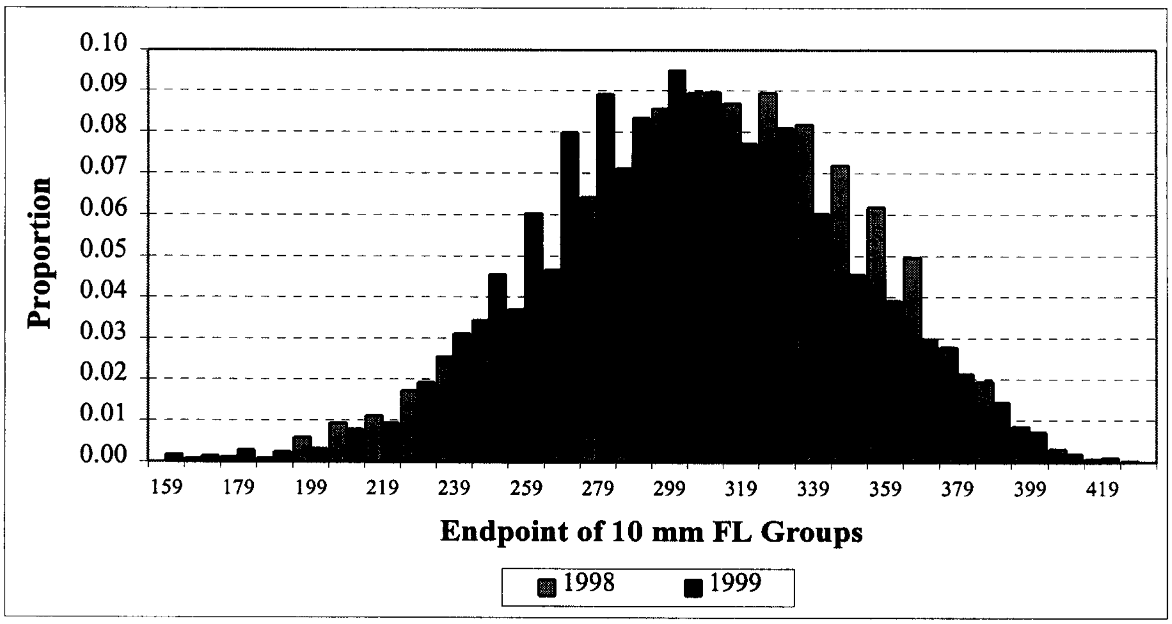
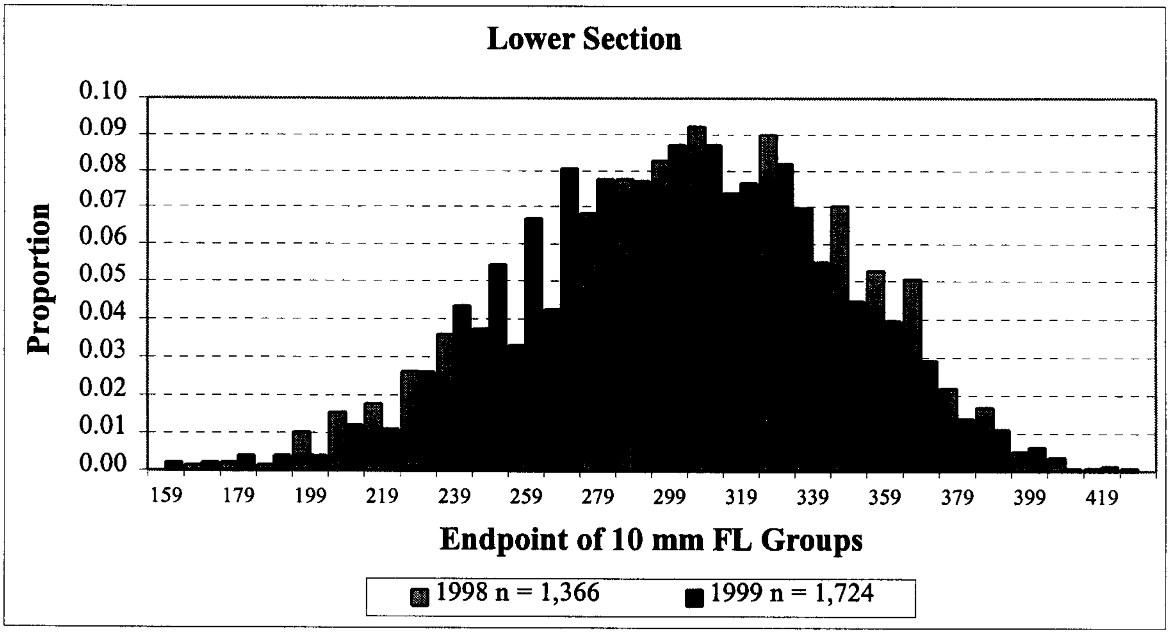


Figure 6.-Cumulative distributive functions (cdf) and length frequency of fork lengths of Arctic grayling captured in 1998 versus those captured in 1999 in the lower 144 km of the Chena River.



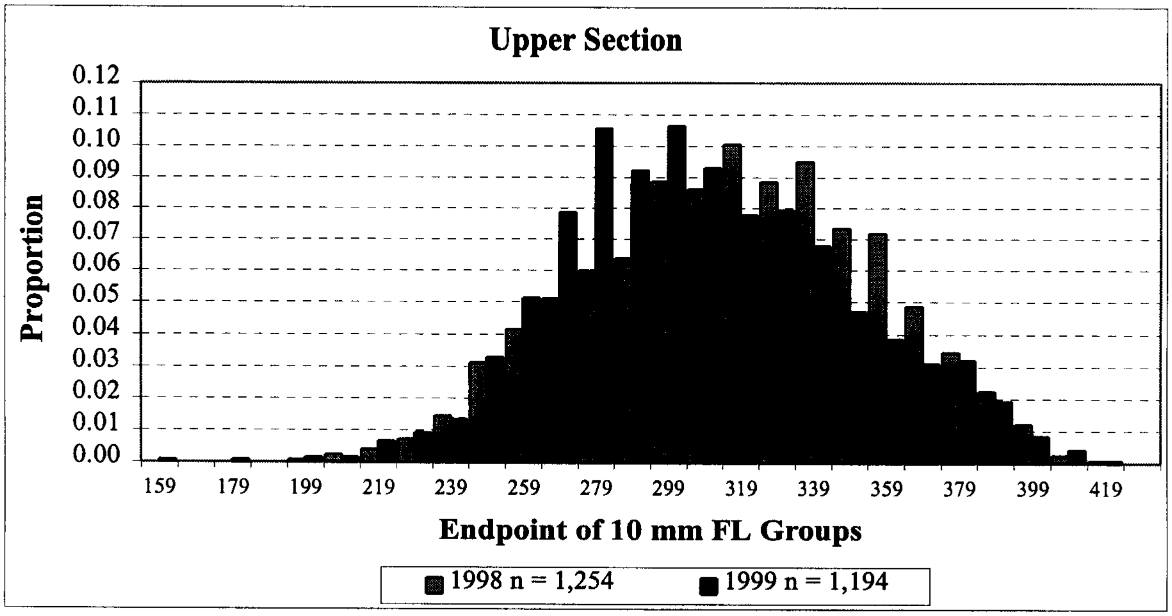


Figure 7.-Length frequency of fork lengths of Arctic grayling captured in 1998 versus those captured in 1999 in the lower and upper sections of the Chena River.

Table 12.-Abundance of Arctic grayling ≥ 270 mm FL, number of fish sampled, and proportion marked in May and number of fish recaptured in July with May tags, proportion of July fish with tags, and proportion of July fish that were also present in May by section of the study area (the lower 144 km of the Chena River), 1998.

At Tagging in May					At Recapture in July						
Section	N_m[a]	SE[N_m]	n_m[b]	p_t[c]	Section	n_j[d]	c_m[e]	SE[c_m]	p_m[f]	p_c[g]	SE[p_c]
Lower	7,704	1,673	1,056	0.14	Lower	515	17	4	0.03	0.24	0.08
					Upper	1,182	25	5	0.02	0.15	0.04
					Both	1,697	42	6	0.02	0.18	0.05
Upper	11,157	1,846	1,058	0.10	Lower	515	0	0	0.00	0.00	0.00
					Upper	1,182	38	6	0.03	0.34	0.08
					Both	1,697	38	6	0.02	0.24	0.05
Both	18,861	2,491	2,116	0.11	Both	1,697	80	9	0.05	0.42	0.07

[a] N_m = population abundance in May

[b] n_m = number of fish tagged in May.

[c] p_t = proportion of fish in May population that were tagged, i.e. May tagging rate.

[d] n_j = number of fish in the July sample examined for tags applied in May.

[e] c_m = number of fish in the July sample that bore May tags.

[f] p_m = proportion of fish in July population that were tagged in May, i.e. recapture rate of May tags

[g] p_c = proportion of fish in July population that were present in May, i.e. contribution rate of the May population to the July population.

HOMING

For 82 Arctic grayling marked in May 1998 and recovered in May 1999, distance from the location of marking to the location of recovery averaged 1.9 km (median = 0.0 km). Distances from the location of marking ranged from 24 km upstream to 74 km downstream and 10 fish were recovered at the same location of marking (Table 13). Fish marked in the upper study section were recovered a greater distance from location of marking on average (5.4 km downstream; SD = 15.8 km) than fish marked in the lower study section (3.2 km upstream; SD = 6.4 km; Table 13). Adult fish were recovered farther from location of marking than immature fish.

Eighty-five percent (SE = 6%) of fish marked in the lower section, 61% (SE = 7%) of fish marked in the upper section, and 71% (SE = 5%) of all fish marked in the study area were recovered within 8 km of the location of marking (Tables 14, 15, and 16, respectively). Of all fish marked and recovered, 35% (SE = 5%) were recovered within 2 km of the location of marking (Table 16).

MATURITY

Onset of maturity at age was age-4 (fifth year of life) for 1,062 fish in 1998 and age-5 for 924 fish in 1999 (Table 17). All fish were mature at age-9 in 1998 and age-11 in 1999. Fish exceeded 50% maturity at age-6 in 1998 and age-7 in 1999.

Onset of maturity was between 220 mm FL and 229 mm FL for 2,620 fish in 1998 and for 2,918 fish in 1999 (Table 18). All fish were mature between 370 and 379 mm FL in 1998 and 390 and 399 mm FL in 1999. Fish exceeded 50% maturity between 280 and 289 mm FL in 1998 and 1999.

ANGLER RETURNS

In the first season after release, anglers reported capturing 86 fish tagged in May 1998 and 1999 or 2% of all fish tagged. Specific locations were reported for 80 of these, general locations for two and no locations were given for four. Average distance recovered from location of marking was 49 km upstream (SD = 42 km) and ranged from 32 km downstream to 133 km upstream (Table 19). Fork lengths of these fish averaged 313 mm (SD = 38 mm) and ranged from 155 mm to 385 mm (Table 19). Fish were recovered, on average, 43 days after tagging (SD = 29 days) and ranged from the same day of marking to 142 days after marking (Table 19).

Anglers reported recovering marked fish throughout the study area including the North Fork Chena, East Fork Chena, and West Fork Chena rivers. No recoveries were made in Badger Slough, Little Chena River, or the South Fork Chena River. Of fish recovered by anglers and reported, 49% (SE = 9%) were recovered upstream of the study area in which these fish were marked. Of fish recovered by anglers between June 15 and August 15 and reported to ADF&G, 70% (SE = 7%) were recovered upstream of the study area (Table 20). A greater proportion of upstream anglers, however, may be more inclined to report tag recoveries to ADF&G.

DISCUSSION

In using the Robson-Flick model, two major assumptions were that the first sample was unbiased and that fish return to the same spawning area each year. Due to the implications of recruitment, mortality, and movement during the year between events, the standard hypothesis tests to determine size and area selectivity were ineffective in determining bias. For this reason, the

Table 13.-Mean, median, minimum, and maximum distances recaptured from location of marking for 82 Arctic grayling marked in May 1998 and recaptured in May 1999 by section of study area and maturity, Chena River.

	Distances From Location of Marking (km)[a]					
	n	Mean	SD	Median	Min	Max
Lower Section	33	3.2	6.4	2	-6	18
Upper Section	49	-5.4	15.8	-2	-74	24
Total	82	-1.9	13.5	0	-74	24
Mature	61	-2.8	14.2	0	-74	24
Immature	21	0.8	11.2	2	-40	18

[a] Negative numbers denote downstream distances from release sites. Positive numbers denote upstream distances from release sites.

Table 14.-Proportion of Arctic grayling recovered in May 1999 at a location different than the location of marking in May 1998 by distances from marking location, direction, and by sex and maturity in the lower section of the study area, Chena River.

	Females			Males			Immature			Subtotal Adults			Total		
Km	n	p	SE[p]	n	p	SE[p]	n	p	SE[p]	n	p	SE[p]	n	p	SE[p]
26 – 40	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00
18 – 24	1	0.20	0.20	0	0.00	0.00	1	0.17	0.17	1	0.04	0.04	2	0.06	0.04
10 – 16	0	0.00	0.00	2	0.09	0.06	1	0.17	0.17	2	0.07	0.05	3	0.09	0.05
3 – 8	2	0.40	0.24	6	0.27	0.10	1	0.17	0.17	8	0.30	0.09	9	0.27	0.08
2 - -2	2	0.40	0.24	10	0.45	0.11	1	0.17	0.17	12	0.44	0.10	13	0.39	0.09
-3 - -8	0	0.00	0.00	4	0.18	0.08	2	0.33	0.21	4	0.15	0.07	6	0.18	0.07
-10 - -16	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00
-18 - -24	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00
-26 - -40	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00
Total	5	1.00	0.00	22	1.00	0.00	6	1.00	0.00	27	1.00	0.00	33	1.00	0.00
8 - -8	4	0.80	0.20	20	0.91	0.06	4	0.67	0.21	24	0.89	0.06	28	0.85	0.06
Upstream	3	0.60	0.24	8	0.36	0.10	3	0.50	0.22	11	0.41	0.10	14	0.42	0.09
No change	2	0.40	0.24	10	0.45	0.11	1	0.17	0.17	12	0.44	0.10	13	0.39	0.09
Downstream	0	0.00	0.00	4	0.18	0.08	2	0.33	0.21	4	0.15	0.07	6	0.18	0.07

Table 15.-Proportion of Arctic grayling recovered in May 1999 at a location different than the location of marking in May 1998 by distances from marking location, direction, and by sex and maturity in the upper section of the study area, Chena River.

	Females			Males			Immature			Subtotal Adults			Total		
Km	n	p	SE[p]	n	p	SE[p]	n	p	SE[p]	n	p	SE[p]	n	p	SE[p]
26 – 40	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00
18 – 24	2	0.18	0.12	1	0.04	0.04	0	0.00	0.00	3	0.09	0.05	3	0.06	0.03
10 – 16	0	0.00	0.00	0	0.00	0.00	1	0.07	0.07	0	0.00	0.00	1	0.02	0.02
3 – 8	1	0.09	0.09	3	0.13	0.07	5	0.33	0.13	4	0.12	0.06	9	0.18	0.06
2 - -2	3	0.27	0.14	6	0.26	0.09	7	0.47	0.13	9	0.26	0.08	16	0.33	0.07
-3 - -8	1	0.09	0.09	4	0.17	0.08	0	0.00	0.00	5	0.15	0.06	5	0.10	0.04
-10 - -16	3	0.27	0.14	4	0.17	0.08	1	0.07	0.07	7	0.21	0.07	8	0.16	0.05
-18 - -24	1	0.09	0.09	1	0.04	0.04	0	0.00	0.00	2	0.06	0.04	2	0.04	0.03
-26 - -40	0	0.00	0.00	4	0.17	0.08	1	0.07	0.07	4	0.12	0.06	5	0.10	0.04
Total	11	1.00	0.00	23	1.00	0.00	15	1.00	0.00	34	1.00	0.00	49	1.00	0.00
8 - -8	5	0.45	0.16	13	0.57	0.11	12	0.80	0.11	18	0.53	0.09	30	0.61	0.07
Upstream	3	0.27	0.14	4	0.17	0.08	6	0.40	0.13	7	0.21	0.07	13	0.27	0.06
No change	3	0.27	0.14	6	0.26	0.09	7	0.47	0.13	9	0.26	0.08	16	0.33	0.07
Downstream	5	0.45	0.16	13	0.57	0.11	2	0.13	0.09	18	0.53	0.09	20	0.41	0.07

Table 16.-Proportion of Arctic grayling recovered in May 1999 at a location different than the location of marking in May 1998 by distances from marking location, direction, and by sex and maturity in the study area, Chena River.

	Females			Males			Immature			Subtotal Adults			Total		
Km	n	p	SE[p]	n	p	SE[p]	n	p	SE[p]	n	p	SE[p]	n	p	SE[p]
26 - 40	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00
18 - 24	3	0.19	0.10	1	0.02	0.02	1	0.05	0.05	4	0.07	0.03	5	0.06	0.03
10 - 16	0	0.00	0.00	2	0.04	0.03	2	0.10	0.07	2	0.03	0.02	4	0.05	0.02
3 - 8	3	0.19	0.10	9	0.20	0.06	6	0.29	0.10	12	0.20	0.05	18	0.22	0.05
2 - -2	5	0.31	0.12	16	0.36	0.07	8	0.38	0.11	21	0.34	0.06	29	0.35	0.05
-3 - -8	1	0.06	0.06	8	0.18	0.06	2	0.10	0.07	9	0.15	0.05	11	0.13	0.04
-10 - -16	3	0.19	0.10	4	0.09	0.04	1	0.05	0.05	7	0.11	0.04	8	0.10	0.03
-18 - -24	1	0.06	0.06	1	0.02	0.02	0	0.00	0.00	2	0.03	0.02	2	0.02	0.02
-26 - -40	0	0.00	0.00	4	0.09	0.04	1	0.05	0.05	4	0.07	0.03	5	0.06	0.03
Total	16	1.00	0.00	45	1.00	0.00	21	1.00	0.00	61	1.00	0.00	82		
8 - -8	9	0.56	0.13	33	0.73	0.07	16	0.76	0.10	42	0.69	0.06	58	0.71	0.05
Upstream	6	0.38	0.13	12	0.27	0.07	9	0.43	0.11	18	0.30	0.06	27	0.33	0.05
No change	5	0.31	0.12	16	0.36	0.07	8	0.38	0.11	21	0.34	0.06	29	0.35	0.05
Downstream	5	0.31	0.12	17	0.38	0.07	4	0.19	0.09	22	0.36	0.06	26	0.32	0.05

Table 17.-Number mature, proportion mature, and standard error of proportions by age for Arctic grayling (≥ 150 mm FL) captured by pulsed-DC electrofishing from the lower 144 km of the Chena River, 29 April through 9 May 1998 and 10 through 13 May 1999.

	1998				1999				Combined			
Age	N[a]	m[b]	p[m]	SE[m]	n	m	p[m]	SE[m]	n	m	p[m]	SE[m]
2	0	---	---	---	3	0	0.00	0.00	3	0	0.00	0.00
3	11	0	0.00	0.00	13	0	0.00	0.00	24	0	0.00	0.00
4	37	2	0.05	0.04	23	0	0.00	0.00	60	2	0.03	0.02
5	182	35	0.19	0.03	118	11	0.09	0.03	300	46	0.15	0.02
6	186	118	0.63	0.04	246	72	0.29	0.03	432	190	0.44	0.02
7	268	242	0.90	0.02	209	158	0.76	0.03	477	400	0.84	0.02
8	220	212	0.96	0.01	170	155	0.91	0.02	390	367	0.94	0.01
9	101	101	1.00	0.00	92	88	0.96	0.02	193	189	0.98	0.01
10	44	44	1.00	0.00	38	36	0.95	0.04	82	80	0.98	0.02
11	9	9	1.00	0.00	10	10	1.00	0.00	19	19	1.00	0.00
12	3	3	1.00	0.00	2	2	1.00	0.00	5	5	1.00	0.00
13	1	1	1.00	0.00	0	---	---	---	1	1	1.00	0.00
Total	1,062	767	0.72	0.01	924	532	0.58	0.02	1,986	1,299	0.65	0.01

[a] n= number of Arctic grayling sampled at age.

[b] m = number of mature Arctic grayling at age.

Table 18.-Number mature, proportion mature, and standard error of proportions by size category for Arctic grayling (≥ 150 mm FL) captured by pulsed-DC electrofishing from the lower 144 km of the Chena River, 29 April through 9 May 1998 and 10 through 13 May 1999.

	1998				1999				Both			
Group	n[a]	m[b]	p[m]	SE[p]	n	m	P[m]	SE[p]	n	m	p[m]	SE[p]
150-159	0	0	---	---	5	0	0.00	---	5	0	0.00	---
160-169	2	0	0.00	0.00	4	0	0.00	---	6	0	0.00	---
170-179	3	0	0.00	0.00	8	0	0.00	---	11	0	0.00	---
180-189	2	0	0.00	0.00	7	0	0.00	---	9	0	0.00	---
190-199	15	0	0.00	0.00	9	0	0.00	---	24	0	0.00	---
200-209	24	0	0.00	0.00	23	0	0.00	---	47	0	0.00	---
210219	29	0	0.00	0.00	27	0	0.00	---	56	0	0.00	---
220-229	45	2	0.04	0.03	56	3	0.05	0.03	101	5	0.05	0.02
230-239	67	5	0.07	0.03	91	6	0.07	0.03	158	11	0.07	0.02
240-249	90	16	0.18	0.04	133	15	0.11	0.03	223	31	0.14	0.02
250-259	97	17	0.18	0.04	176	33	0.19	0.03	273	50	0.18	0.02
260-269	122	42	0.34	0.04	233	70	0.30	0.03	355	112	0.32	0.02
270-279	168	75	0.45	0.04	260	101	0.39	0.03	428	176	0.41	0.02
280-289	186	111	0.60	0.04	243	123	0.51	0.03	429	234	0.55	0.02
290-299	224	157	0.70	0.03	277	164	0.59	0.03	501	321	0.64	0.02
300-309	234	196	0.84	0.02	261	192	0.74	0.03	495	388	0.78	0.02
310-319	227	211	0.93	0.02	225	191	0.85	0.02	452	402	0.89	0.01
320-329	234	226	0.97	0.01	236	220	0.93	0.02	470	446	0.95	0.01
330-339	214	211	0.99	0.01	176	170	0.97	0.01	390	381	0.98	0.01
340-349	188	187	0.99	0.01	133	124	0.93	0.02	321	311	0.97	0.01
350-359	162	160	0.99	0.01	114	112	0.98	0.01	276	272	0.99	0.01
360-369	130	129	0.99	0.01	87	83	0.95	0.02	217	212	0.98	0.01
370-379	73	73	1.00	0.00	62	59	0.95	0.03	135	132	0.98	0.01
380-389	51	49	0.96	0.03	42	36	0.86	0.05	93	85	0.91	0.03
390-399	22	22	1.00	0.00	21	21	1.00	0.00	43	43	1.00	0.00
400-409	8	8	1.00	0.00	6	6	1.00	0.00	14	14	1.00	0.00
400-419	2	2	1.00	0.00	3	3	1.00	0.00	5	5	1.00	0.00
410-429	1	1	1.00	0.00	0	0	---	---	1	1	1.00	0.00
	2,620	1,900	0.73	0.01	2,918	1,732	0.59	0.(	5,538	3,632	0.66	0.01

[a] n= number of Arctic grayling sampled at age.

b m = number of mature Arctic grayling at age.

Table 19.-Mean, median, minimum, and maximum number of kilometers moved, fork lengths at release, and days after release of Arctic grayling recaptured by anglers in the year of release, Chena River 1998 and 1999.

Year	n	Mean	SD	Median	Min	Max
			Kilometers:			
1998	29	44	43	34	-18	123
1999	51	52	41	57	-32	133
Total	82	49	42	46	-32	133
			Fork length:			
1998	30	323	33	318	256	383
1999	56	308	40	306	155	385
Total	86	313	38	314	155	385
			Days out:			
1998	30	40	30	36	0	107
1999	56	45	28	40	3	142
Total	86	43	29	37	0	142

[a] Negative numbers denote downstream distances from release sites. Positive numbers denote upstream distances from release sites.

Table 20.-Number of Arctic grayling marked in May 1998 and May 1999, number recovered by anglers in the same year of marking, rate of recapture (R/M), recovery area, and proportion recovered outside of area marked by time of recapture and section of study area, Chena River.

				Recovery Areas[d]					
Section	m[a]	r[b]	R/M[c]	Unk	Lower	Upper	Outside	p[Out]	SE[p]
				All Recaptures					
1998:									
Lower	1,366	14	0.01	0	5	3	6	0.43	0.14
Upper	1,252	16	0.01	0	1	8	7	0.44	0.13
Subtotal	2,618	30	0.01	0	6	11	13	0.43	0.09
1999:									
Lower	1,506	25	0.02	1	7	7	10	0.40	0.10
Upper	1,040	31	0.03	3	0	9	19	0.61	0.09
Subtotal	2,546	56	0.02	4	7	16	29	0.52	0.07
Total	5,164	86	0.02	4	13	27	42	0.49	0.05
				Only Recaptures Made 6/15 - 8/15					
1998:									
Lower	1,366	6	<0.01	0	0	1	5	0.83	0.17
Upper	1,252	7	0.01	0	0	3	4	0.57	0.20
Subtotal	2,618	13	0.01	0	0	4	9	0.69	0.13
1999:									
Lower	1,506	13	0.01	1	1	4	8	0.62	0.14
Upper	1,040	18	0.02	3	0	4	14	0.78	0.10
Subtotal	2,546	31	0.01	4	1	8	22	0.71	0.08
Total	5,164	44	0.01	4	1	12	31	0.70	0.07

a m = number of fish released with tags.

b r = number of tagged fish captured by anglers.

c R/M = recapture rate by anglers.

d Recovery areas: Lower = lower section of the study area; Upper = upper section of the study area; Outside = drainage locations outside the study area.

Robson-Flick model requires the use of only fish that were fully recruited to the gear. Therefore, the estimated population was for fish ≥ 270 mm FL. When considering fish not fully recruited to the gear (< 270 mm FL), estimates are minimum estimates.

Homing to spawning areas is less apparent in this study than that found in the Goodpaster in 1996 and 1997. In this study only 69% of adult recaptures were made within 8 km of site of marking (Table 16) compared to 76% to 82% in the Goodpaster. In the Goodpaster, 53% to 60% of adult fish were recovered at the location of marking compared to 34% of adult fish in this study. No recoveries were made 5 km upstream of the end of the 1998 marking area. Also, no mature Badger Slough fish that were tagged during spawning in 1996 were recovered in the study area in May 1998. The lack of recoveries from Badger Slough spawners in the mainstem Chena River in May contrasts with 11 recoveries of Badger Slough spawners in July 1997 and 9 in July 1998. With this evidence it is believed that the assumption of homing, or that spawners generally return to the same place to spawn from one year to the next is valid.

A comparison of abundance in the study area between May and July of 1998 indicates that the number of fish ≥ 270 mm FL was similar (Table 21). The lower section of the study area, however, shows a difference in the number of both quality (270 mm – 339 mm FL) and preferred sized (≥ 340 mm FL) fish between May and July. The May population of fish ≥ 270 mm FL (7,704; SE = 1,673) in the lower section of the study area was 370% greater than the July population (1,804; SE = 427; Table 21). In the upper section, only preferred-sized fish were significantly more abundant in May (3,495; SE = 578) than in July (1,095; SE = 347; Table 21).

The proportion of July fish that were also present in May (0.42; SE = 0.07; Table 16), was similar to that found in the Goodpaster River. For the Goodpaster River, the proportion of August fish that were also present in May was 0.32 in 1995 (Se = 0.12) and 0.76 (SE = 0.22) in 1996 (Ridder 1998b).

The July abundance of fish in the Chena River drainage upstream of the study area was derived by extrapolation. Fish present in the study area in May but not in July were assumed to be present upstream of the study area and not in the Little Chena River or outside of the drainage. In some rivers, however, fish move outside the drainage after spawning. In the Goodpaster River a number of fish leave the Goodpaster River after spawning.

All angler recaptures of May fish reported to ADF&G were caught in or upstream of the study area. One angler, however, reportedly recovered a tagged grayling in Bear Creek, a tributary to the Tanana River downstream of the confluence of the Chena River (C. Schwanke, Alaska Department of Fish and Game, Fairbanks, personal communication). This fish may not have been a fish that spawned in the Chena River. Even with these concerns, the estimate of abundance for fish upstream of the study area is considered reliable. The estimated density of Arctic grayling in the 319 km reach upstream of the study area in July was 109 fish ≥ 270 mm FL per km compared to 99 fish ≥ 270 mm FL per km in the study area in July. Combining the two estimates of July results in an estimate of 49,000 fish ≥ 270 mm FL in the Chena River in 1998.

There were differences in the sex ratios of adult fish (Appendix B3) and distribution of males in the upper section of the study area between 1998 and 1999 (Table 2). This may be the result of differences in water conditions between years. There were greater discharge, turbidity, and lower temperatures in the upper study section in 1999 than in 1998 (Figures 4 and 5). Displacement of Arctic grayling or changes in gear efficiency by high turbid flows has not been

Table 21.-Abundance, standard errors, and 95% confidence intervals of quality-sized and larger Arctic grayling (≥ 270 mm FL) in the upper, lower, and combined sections of the study area of the Chena River, May and July 1998.

	May				July[a]			
Group	N	SE[N]	-95CI	+95CI	N	SE[N]	-95CI	+95CI
				Lower section:				
270 - 339	5,291	1,149	3,039	7,543	1,728	426	894	2,563
≥ 340	2,413	524	1,386	3,440	75	24	27	123
subtotal	7,704	1,673	4,425	10,983	1,804	427	968	2,640
				Upper section:				
270 - 339	7,662	1,286	5,141	10,183	11,424	2,022	7,461	15,386
≥ 340	3,495	578	2,362	4,628	1,095	347	414	1,776
subtotal	11,157	1,846	7,539	14,775	12,519	2,051	8,498	16,539
				Both:				
270 - 339	13,204	1,775	9,725	16,683	13,152	1,832	9,562	16,742
≥ 340	5,657	815	4,060	7,254	1,170	174	830	1,510
total	18,861	2,491	13,979	23,743	14,322	1,840	10,716	17,928

[a] July data is from Ridder 1999.

investigated but has been observed. In this study, the largest catches of adults were made immediately above and within riffle areas in May 1998. This was a time when water was low and clear. The largest catches in May 1999, however, were from backwater areas above and below riffle areas. This was a time when water was turbid and high. Given that males defend spawning sites in riffles and females hold in nearby pools, differing water conditions may favor one sex or another given the same capture method. With the high and turbid water in 1999, riffle areas were hard to distinguish but backwater areas were not and females were caught in greater numbers and males in lesser numbers than in 1998 resulting in a 1:1 male to female ratio in 1999 and 2:1 ratio in 1998. This change in sex ratio was also found in the Goodpaster River in 1999 when water conditions were similar. Sex ratios that favored males, > 2:1 were found from 1995 to 1998 whereas the ratio was 1:1 in 1999 (Ridder 1998b; F. Parker, Alaska Department of Fish and Game, Delta Junction, personal communication).

Water temperatures and discharge may have also effected the locations of recaptured fish in 1999 when recovery location was predominantly downstream of marking location. This was especially true for those fish tagged in the upper section where water temperatures were coldest and discharge greatest. Ridder (1998c) found that overwintering areas were generally downstream of spawning areas and Tack (1980) found that temperatures of 1 C^{o} elicited an upstream spring migration in the Goodpaster River.

Age and length at maturity, estimated in 1998 and 1999, indicates a tendency towards older and larger fish than that estimated in 1991 and 1992 (Clark 1992b; Tables 22 and 23). This may be a consequence of the no harvest regulation imposed in 1991. There, however, may also be an affect from the uncertainty and variability of sexing fish among years and the affect cold water temperatures and sample timing have on maturity. In the earlier estimates, sexing was conducted during the end of May when warmer water temperatures were more likely than earlier in May.

Within this report is the first estimate of the population of Arctic grayling outside of the summer period. The data and estimated parameters from the May population parallel those obtained in the Goodpaster River studies. The lower river is important for spawning and those spawners move out of the assessed area is an obvious conclusion. How all these spawners, in the study area and those spawning in the upper river, relate to what we find in the study area in July is a continuing question for researchers. Management of the Chena River fishery should not rely only on July sampling in the study area but sampling at other times and areas since this population is spatially and temporally stratified.

Table 22.-Estimated number sampled, number mature, proportion mature, and standard error of proportion by age for Arctic grayling ($\geq$ 150 mm FL) captured by pulsed-DC electrofishing from the lower 144 km of the Chena River, spring 1991 - 1992 and 1998 - 1999.

	1991 – 1992				1998 – 1999			
Age	n[a]	m[b]	p[m]	SE[m]	n	m	P[m]	SE[m]
2	5	0	0.00	0.00	3	0	---	---
3	39	0	0.00	0.00	24	0	---	---
4	170	3	0.02	0.01	60	2	0.03	0.02
5	265	40	0.15	0.02	300	46	0.15	0.02
6	78	57	0.73	0.05	432	190	0.44	0.02
7	91	86	0.95	0.02	477	400	0.84	0.02
8	79	75	0.95	0.02	390	367	0.94	0.01
9	21	20	0.95	0.05	193	189	0.98	0.01
10	9	9	1.00	0.00	82	80	0.98	0.02
11	2	2	1.00	0.00	19	19	1.00	0.00
12	0	0	---	---	5	5	1.00	0.00
13	0	0	---	---	1	1	1.00	---
Total	759	292	0.38	0.02	1,986	1,299	0.65	0.01

[a] n= number of Arctic grayling sampled at age.

[b] m = number of mature Arctic grayling at age.

Table 23.-Estimated number maturity, proportion mature, standard error of proportion by length category for Arctic grayling (≥ 150 mm FL) captured by pulsed-DC electrofishing from the lower 144 km of the Chena River, spring 1991 - 1992 and 1998 - 1999.

	1991 - 1992				1998 – 1999			
Group	n[a]	m[b]	p[m]	SE[p]	n	m	p[m]	SE[p]
150-159	2	0	0.00	0.00	5	0	0.00	---
160-169	3	0	0.00	0.00	6	0	0.00	---
170-179	4	0	0.00	0.00	11	0	0.00	---
180-189	8	0	0.00	0.00	9	0	0.00	---
190-199	16	0	0.00	0.00	24	0	0.00	---
200-209	36	0	0.00	0.00	47	0	0.00	---
210-219	43	1	0.02	0.02	56	0	0.00	---
220-229	70	1	0.01	0.01	101	5	0.05	0.02
230-239	77	1	0.01	0.01	158	11	0.07	0.02
240-249	101	7	0.07	0.03	223	31	0.14	0.02
250-259	91	13	0.14	0.04	273	50	0.18	0.02
260-269	76	20	0.26	0.05	355	112	0.32	0.02
270-279	63	36	0.57	0.06	428	176	0.41	0.02
280-289	59	44	0.75	0.06	429	234	0.55	0.02
290-299	45	40	0.89	0.05	501	321	0.64	0.02
300-309	30	28	0.93	0.05	495	388	0.78	0.02
310-319	37	37	1.00	0.00	452	402	0.89	0.01
320-329	32	32	1.00	0.00	470	446	0.95	0.01
330-339	27	27	1.00	0.00	390	381	0.98	0.01
340-349	36	36	1.00	0.00	321	311	0.97	0.01
350-359	21	21	1.00	0.00	276	272	0.99	0.01
360-369	9	9	1.00	0.00	217	212	0.98	0.01
370-379	6	6	1.00	0.00	135	132	0.98	0.01
380-389	5	5	1.00	0.00	93	85	0.91	0.03
390-399	1	1	1.00	---	43	43	1.00	0.00
400-409	0	---	---	---	14	14	1.00	0.00
400-419	0	---	---	---	5	5	1.00	0.00
410-429	0	---	---	---	1	1	1.00	---
	898	365	0.41	0.02	5,538	32	0.66	0.01

[a] n= number of Arctic grayling sampled at age.

[b] m = number of mature Arctic grayling at age.

ACKNOWLEDGMENTS

The author extends thanks to the following people for their assistance during field sampling: Steve Bethune, Richard Bettinger, Wolf Cartusceillo, Doug Edwards; Doug Fleming, Jim Fish, Jerry Hallberg, Ted Lambert, Monica McGillery, Rick Queen, Don Roach, Corey Schwanke, and Klaus Wuttig; to Mac Minard and Margaret Merritt for providing the administrative structure necessary for implementing this project; to Lisa Stuby for preparing and aging scale samples, and to Mike Wallendorf for biometric review. Lastly, thanks to Sara Case for preparing this report for printing. This project and report were made possible by partial funding provided by the U.S. Fish and Wildlife Service through the Federal Aid in Sport Fish Restoration Act (16 U.S.C. 777-777K) under project F-10-15, Job Number R-3-2(a).

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APPENDIX A
Data File Listing

Appendix A1.-Data files[a] used to estimate parameters of the Arctic grayling population in the Chena River in 1998 and 1999.

Data File	Description
U-000200L021998.dta	Total catch data for Arctic grayling captured in the lower section (river km 0-72) of the Chena River study area 29 April – 5 May 1998
U-000100L011998.dta	Total catch data for Arctic grayling captured in the upper section (river km 72-138) of the Chena River study area 6 - 9 May 1998
U-000200L011999.dta	Total catch data for Arctic grayling captured in the lower section (river km 0-72) of the Chena River study area 10 - 11 May 1999
U-000100L011999.dta	Total catch data for Arctic grayling captured in the upper section (river km 72-144) of the Chena River study area 12 - 13 May 1999

[a] Data files have been archived at, and are available from the Alaska Dept Fish and Game, Sport Fish, Research and Technical Services, 333 Raspberry Road, Anchorage, Alaska 99518-1599.

APPENDIX B

Appendix B1.-Catch by sex and maturity of females by date, river kilometer, and year (29 April through 9 May 1998 and 10 through 13 May 1999).

							Females								
	River	Catch					Green			Ripe			Spent		
Date	Km	Total	Males	Females	Unknowns	M:F	n	p	SE	N	p	SE	n	p	SE
1998 (Lower 138 Km of the Chena River)															
4/30-5/1	0-24	233	144	43	46	3.3	36	0.84	0.02	5	0.12	0.03	0	0.00	0.00
4/29-30	24-40	356	207	64	85	3.2	59	0.92	0.01	9	0.14	0.03	0	0.00	0.00
5/4-5	40-56	528	326	112	90	2.9	61	0.54	0.02	37	0.33	0.05	13	0.12	0.05
5/4	56-72	256	132	56	68	2.4	43	0.77	0.02	13	0.23	0.04	0	0.00	0.00
5/7-8	72-90	301	134	77	90	1.7	43	0.56	0.02	23	0.30	0.04	11	0.14	0.06
5/6	90-107	130	67	19	44	3.5	13	0.68	0.02	5	0.26	0.04	1	0.05	0.04
5/8	107-125	335	81	71	183	1.1	53	0.75	0.02	14	0.20	0.04	3	0.04	0.03
5/8-9	125-138	492	191	184	117	1.0	168	0.91	0.01	3	0.02	0.01	8	0.04	0.03
Totals	0-138	2,631	1,282	626	723	2.0	476	0.76	0.02	109	0.17	0.04	36	0.06	0.04
1999 (Lower 144 Km of the Chena River)															
5/10	0-24	254	101	78	75	1.3	60	0.77	0.05	18	0.23	0.05	0	0.00	---
5/10	24-40	601	216	183	202	1.2	152	0.94	0.02	9	0.06	0.02	1	0.01	0.01
5/11	40-56	532	190	191	151	1.0	122	0.93	0.02	9	0.07	0.02	0	0.00	---
5/11	56-72	345	104	134	107	0.8	79	0.60	0.04	51	0.39	0.04	1	0.01	0.01
5/12	72-90	447	100	88	259	1.1	nd	---	---	Nd	---	---	nd	---	---
5/12	90-107	213	43	43	127	1.0	30	0.70	0.07	12	0.28	0.07	1	0.02	0.02
5/13	107-125	321	75	53	193	1.4	nd	---	---	Nd	---	---	nd	---	---
5/13	125-144	215	76	60	79	1.3	51	0.85	0.05	4	0.07	0.03	5	0.08	0.04
Totals	0-144	2,928	905	830	1,193	1.1	494	0.82	0.02	103	0.17	0.02	8	0.01	0.00

Appendix B2.-Sample size (n), estimated mean, estimated standard deviation of mean (SD), minimum, and maximum lengths by age for Arctic grayling (≥ 150 mm FL) captured by pulsed-DC electrofishing from the lower 138 km of the Chena River by section, 29 April through 9 May 1998.

	Lower Section of Study Area[a]					Upper Section of Study Area[b]					Study Area				
Age	n	Mean	SD	Min	Max	n	Mean	SD	Min	Max	n	Mean	SD	Min	Max
3	11	191	12	170	211	0	---	---	---	---	11	191	12	170	211
4	29	222	26	193	331	8	232	16	214	259	37	221	16	193	262
5	75	245	22	201	302	107	265	20	217	309	182	257	23	201	309
6	82	278	20	241	315	104	299	22	255	355	186	290	23	241	355
7	124	292	23	242	377	144	319	21	257	389	268	306	25	242	389
8	118	311	21	266	363	102	340	25	286	390	220	324	27	266	390
9	44	329	25	282	389	57	360	20	302	400	101	346	27	282	400
10	23	344	24	292	394	21	356	19	320	398	44	350	23	292	398
11	6	341	12	329	358	3	358	27	337	389	9	346	19	329	389
12	1	405	---	405	405	2	387	21	372	402	3	393	18	372	405
13	1	380	---	380	380	0	---	---	---	---	1	380	---	380	380
Total	514	288	41	170	405	548	313	39	214	402	1,062	301	42	170	405

[a] Lower section of study area was from river-km 0 to 72 (mouth to Chena Dam).

[b] Upper section of study area was from river-km 72 to 138 (Chena Dam to 6 km downstream of the first bridge on Chena Hot Springs Road).

Appendix B3.-Sample size (n), estimated mean, estimated standard deviation of mean (SD), minimum, and maximum lengths by age for Arctic grayling (≥ 150 mm FL) captured by pulsed-DC electrofishing from the lower 138 km of the Chena River by section, 10 through 13 May 1999.

	Lower Section of Study Area[a]					Upper Section of Study Area[b]					Study Area				
Age	n[c]	Mean	SD	Min	Max	n	Mean	SD	Min	Max	n	Mean	SD	Min	Max
2	2	162	9	155	168	0	---	---	---	---	3	160	7	155	168
3	11	202	20	172	227	2	203	47	170	236	13	202	23	170	236
4	15	228	9	204	240	8	238	19	209	260	23	232	14	204	260
5	62	251	18	225	327	56	264	18	222	315	118	257	19	222	327
6	92	279	25	230	370	154	285	20	242	389	246	283	22	230	389
7	125	303	25	258	369	84	311	22	254	359	209	306	24	254	369
8	96	329	24	268	380	74	333	22	283	390	170	331	24	268	390
9	55	336	22	288	393	37	343	22	292	379	92	339	22	288	393
10	21	357	23	328	410	17	362	21	321	392	38	359	22	321	410
11	6	355	13	342	380	4	338	24	303	352	10	348	19	303	380
12	2	344	6	339	348	0	---	---	---	---	2	344	6	339	348
Total	487	299	43	155	410	436	302	36	170	392	924	300	40	155	410

[a] Lower section of study area was from river-km 0 to 72 (mouth to Chena Dam).

[b] Upper section of study area was from river-km 72 to 138 (Chena Dam to 6 km downstream of the first bridge on Chena Hot Springs Road).